University of Alberta

Investment Decision Analysis of Alberta Cattle Industry: A Real Options Approach

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the

requirements for the degree of Master of Science

in

Agricultural and Resource Economics

Department of Rural Economy

Edmonton, Alberta

Spring 2006

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Your file Votre référence
ISBN: 0-494-13808-4
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ISBN: 0-494-13808-4

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Abstract

This thesis extended the discounted cash flow analysis utilized in the investment decision-making process and captured the value of managerial flexibility and adaptability in beef cattle operations via a real options analysis. By estimating model parameters from a historical simulation, numerical option valuation models were employed to determine the real option values and effects associated with the identified investment decisions in distinct sectors within the Alberta cattle industry.

The main objective was to determine the applicability of real options model as a potential capital budgeting procedure for farm managers to evaluate investments in the cattle industry. Findings indicated that the real option models provided innovative insights into the long-term investment decisions in the cow/calf operation under continuously evolving market conditions. However, caution should be suggested in interpreting model results and embodying model assumptions. Performance implications of the real option models in agricultural investments require empirical evidence and future research.

Acknowledgements

This research was funded by Alberta Agriculture, Food and Rural Development (AAFRD), Innovation in Agribusiness Management Fund (IAMF), and Agriculture & Food Council. I would like to thank my supervisor Dr. Jim Unterschultz who generously supplied me with his guidance and incisive feedback throughout the completion of this thesis. I am similarly indebted to Dr. Brian Radke, formerly with Alberta Agriculture, Food and Rural Development, who provided me with his unpublished work on simulation model of cow returns and intelligent insight into this research. I greatly benefited from the data and publications provided by AAFRD and the discussions with production economist Dale Kaliel and other specialists from AAFRD.

Special thanks go to my parents and Ms. Xiaoli Xu for their understanding, encouragement, and unconditional support during the course of my graduate study. Last but not least, thanks to all the staff and colleagues at the Department of Rural Economy for making my study here a most memorable one.

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Chapter 1: Introduction

Beef is the province of Alberta's number one agricultural commodity. The beef cattle industry translates into significant economic benefits for not only rural areas but the entire Alberta community. In year 2004, the cattle industry was providing $2.6 billion in farm cash receipts annually or 32% of total Alberta farm cash receipts (Statistics Canada and Alberta Agriculture, 2005).

Beef cattle operations in Alberta have followed the common trend of growth and concentration that occurred to Canadian farming industry[1]. The size of the province's beef herd has increased from 1.54 million in 1987 to 2.15 million in July 2004 (Statistics Canada, 2005), while the number of beef cow farms in the period of 1987 to 2001 declined by over 14 percent (Statistics Canada, 2001). The consolidation into larger units is likely to realize economies of size at the production level by lowering costs of production (Falconer et al. 1996). However, the larger specialized units expose beef cattle producers to the specific sources of risk associated with the operations.

As shown in Figure 1.1, total farm assets per beef operation unit increased from $602 thousand in 1987 to $1.07 million in 2003 (Statistics Canada, 2004). The current asset portion of the balance sheet increased a modest 17% while intermediate and long term assets (buildings, equipment and land) had gone up by 61.8%. Looking at Figure 1.2, additional capital investments[2] in farm operations now involve larger amounts of money being committed for a long period of time as well as partially irreversible investment outlays. Under the uncertain environment, the decision to increase the amount of money invested in capital intensive beef cattle enterprises competes with other present or future investment opportunities for limited funds.

Traditionally, valuation models that assist with the investment decision-making are discounted cash flow models. However, recent developments in investment analysis have shown that the discounted cash flow models have crucial

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[1] The total number of Canadian farms fell by 22% while average size of farms increased by 32% from 1981 to 2001 (Statistics Canada, 2001 Census of Agriculture).

[2] Capital investment in cattle production includes the investment in beef cow breeding herd, beef cow equipment, beef cow facilities, machinery used to feed cows, and pasture land (Hughes, 1999).

limitations and do not value the ability of the investor to flexibly react in an uncertain and irreversible environment (Dixit and Pindyck, 1994). It is the purpose of this study to extend the discounted cash flow analysis utilized in the beef cattle operations and capture the value of managerial flexibility in the operations via a real options analysis. The real option values inherent in the decisions should contribute to a better understanding of the decision rules and optimal timings of the investments in beef cattle operations. Also the real options approach may help to address the risk and uncertainty associated with these investments.

1.1 Structure of Alberta Cattle Industry

There are three major types of cattle producers in Alberta, the cow/calf producer, backgrounder and finisher. The commercial beef production starts with the cow/calf producer who produces and raises calves from birth to 180-270 kg (400-600 pounds) at weaning. The heavier weaned calves are fed a high energy finishing ration in mid winter and are finished for the spring market. The lighter weaned calves produced in Alberta are "backgrounded" on a low energy feed ration for the winter before they are placed back on grass or on a feedlot finishing program. Once these cattle reach the desired weight, they move to the finishing phase. The highly specialized feedlots feed the cattle with high-energy diets to slaughter market weights. The investment analysis in this study aims at improving the producers' investment decision making associated with all three sectors of the cattle industry.

1.2 Capital Budgeting and Real Options Approach

Capital budgeting procedures are designed to determine whether a large capital investment is profitable and to select between capital investments. Different approaches have been applied to evaluate capital investments by both farm managers and corporate managers, for example the payback period, internal rate of return, and net present value. Among these approaches, the most widely used is the discounted cash flow model, Net Present Value (NPV) (Copeland and Antikarov, 2001). NPV summarizes the expected net cash flow produced by the investment into a single number that is adjusted for risk, inflation and the time value of money (Robison and

Barry, 1996). An investment which produces an NPV greater than zero will provide a return above the minimum required rate of return implied by the discount rate.

Despite its theoretical appeal, many practitioners have recognized that the NPV and other discounted cash flow approaches do not capture the flexibility to adapt and revise later decisions in response to unexpected market development (Trigeorgis et al. 1995). To agricultural investment, flexibility means a farmer is willing and able to take actions to meet new conditions and opportunities. For example, the decision to purchase an additional pen of feeder cattle to place on feed in feedlot operations can be postponed to wait for new information on market prices. Due to the fact that many farmers and cattle feeders lack external sources of equity[3] and are reluctant to disinvest from agriculture[4], it is important to incorporate flexibility into the decision-making throughout their farm operations to cope with various risks. A capital budgeting method with the ability to capture the value of managerial flexibility in capital investments under changing market conditions can be of benefit to farm managers.

The real options (RO) approach is an emerging model applying financial option theory to evaluate investment decisions. The RO approach attempts to capture the value of managerial flexibility (Trigeorgis et al. 1995). For example, the option holder preserves the ability to benefit from a greater upside potential (e.g., option to expand) while limiting the downside risks to the cost of buying an option (e.g., option to abandon). This asymmetric distribution of returns distinguishes real options approach from discounted cash flow approaches which assume a fixed scenario in which an investor starts and completes a project (Remer et al. 2001). The real options approach has been successfully applied in valuation of investments in industries such as natural resource by Brennan and Schwartz (1985), oil reserves by Paddock et al. (1988), and pharmaceutical R&D at Merck (Schwartz and Trigeorgis, 2001). More

---

[3] For most farms, the options of raising equity are limited. It is very unlikely that an individual farm's equity claims will be traded in a liquid market. Only some large, well-established co-ops have been successful in raising outside equity capital (Gloy and LaDue, 2003)

[4] Three quarters of producers in Alberta (75%) indicated that re-investing in their own farm operation made more sense than making non-farm investment according to the Farm Management Practices Benchmark (Ipsos-Reid AgriFood, 2002).

recent applications of the real options framework have valued investments in a wider range of industries. This research explores the feasibility of applying the real options models to the investment decision analysis in beef cattle operations.

1.3 Research Objectives

As a foundation for the practical application of the real options approach to cattle industry investment decisions, this research starts with the review of the principles, issues, and usages of real options approach. Then the numerical methods are introduced to evaluate the real option values associated with the selected investment decisions in the three sectors of the cattle industry.

More specifically, the objectives of this research are:

1) To review the capital budgeting methods used at farm level or recommended by academics to evaluate agricultural investments and to discuss the limitations of their practical applications.
2) To describe and review the methods used for real options valuation in different agriculture related businesses and extract the key principles appropriate for the cattle industry.
3) To identify and assess the main sources of risk associated with the selected short- and long-term investment decisions from the three sectors of the cattle industry.
4) To map different categories of the selected investment decisions from the three sectors of the cattle industry into the space of different types of real options.
5) To use numerical option valuation methods to value the real options inherent in the selected investment decisions from the three sectors of the cattle industry.
6) To use the real option values to measure the effect of irreversibility and uncertainty on investment decision making and investment policy design for individual operations. To evaluate the feasibility of the real options approach in the investment decision analysis in the cattle industry.

This research focuses on the valuation of real options in the capital investment and production decisions complicated by uncertainties in the cattle industry. According to survey results, Alberta producers/ranchers are more likely to have higher level of education and to take advanced farm management training courses than their counterparts in the rest of North America (Ipsos-Reid AgriFood, 2002). Perhaps the advantage in education and knowledge can be leveraged into a better understanding of this innovative capital budgeting method in private investment decision making. It is evaluated whether real options approach has the potential to be a better decision aid in making both short- and long-term investment decisions in the cattle industry.

1.4 Thesis Structure

Chapter 2

This chapter reviews the definitions of capital budgeting (CB) and the real options theory. It first emphasizes the importance of CB methods in agricultural capital investment. Then some major deficiencies of the traditional CB method, NPV, are explained and real options theory is introduced followed by the implication of the potential to use RO in agricultural investments. Finally, several methods of calculating real option values used in the agricultural economics literature are reviewed.

Chapter 3

This chapter starts with a description of the three distinct sectors of the Alberta cattle industry. It provides relevant information for identifying major investment decisions within each sector in the cattle industry. Then the real options inherent in the underlying investment decisions are classified. The main sources of risk in the real options are assessed before applying option pricing algorithms.

Chapter 4

This chapter discusses the methodologies of generating key model parameters of the real option models identified for the underlying investment decisions. Emphasis has been given to the calculation of the economic value of cows associated with the herd expansion/contraction in the cow/calf operation. The chapter also provides a data description. Data are classified according to their availabilities and sources.

Chapter 5

The estimation of the parameters for the spread option inherent in the herd expansion/contraction decision in the cow/calf operation is accomplished by simulating historical returns from the cow herds. This chapter discusses the simulation model validity, estimated volatility and correlation between underlying asset returns in the real option model for the cow/calf operation. Besides the cow/calf sector, the major parameters for the real option valuation model in the feedlot sector are also presented.

Chapter 6

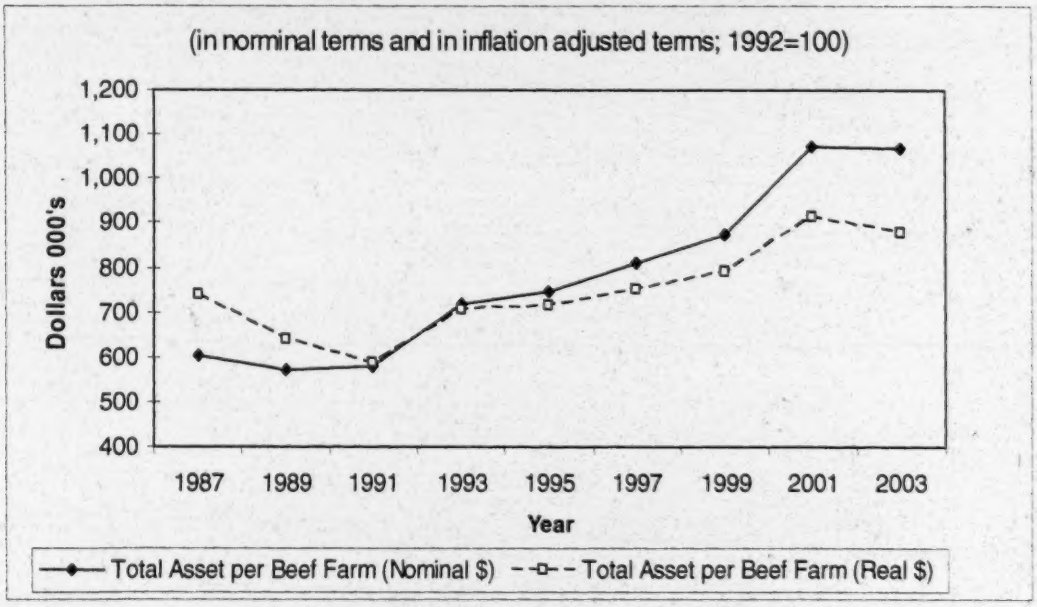
This chapter reviews the results of the real option models in the cattle operations. First, results of the historical simulation model for cow herd expansion/contraction are reviewed, followed by the calculation of the spread option values in the cow/calf sector. Real option values are then used to analyze investment decisions and threshold values associated with investment policy. Next, real option results in the feedlot sector are discussed. Finally, the overall applicability of the real option models to the cattle industry is evaluated.

Chapter 7

This chapter gives a summary of the overall results. The potential impact of using real option models in the cattle industry is reviewed. Limitations of the research and suggestions for future research are discussed.

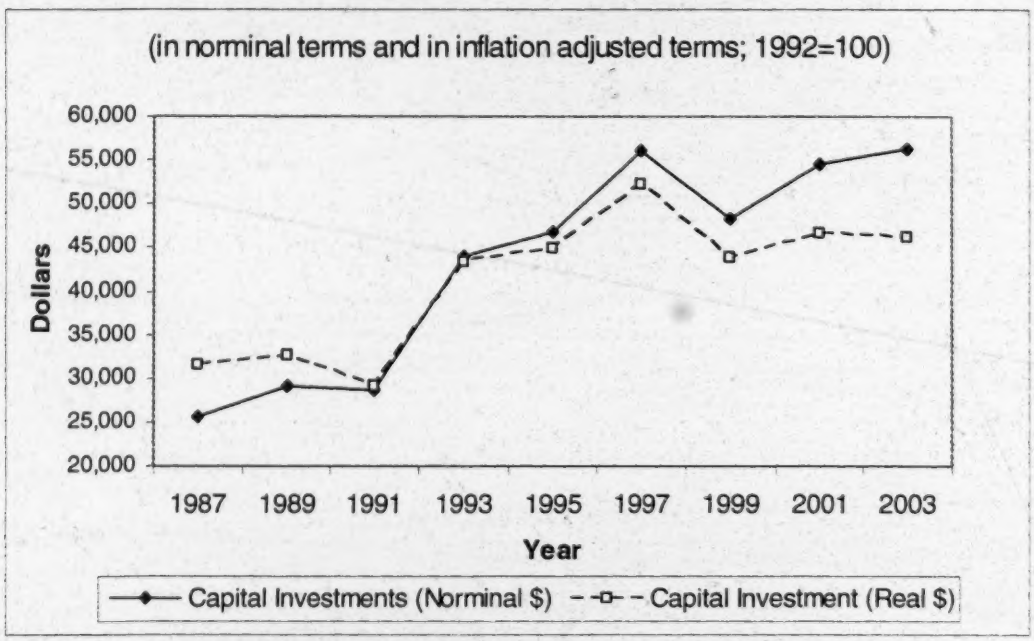
1.5 Figures

Figure 1.1 Average Total Assets of Alberta Beef Farms 1987-2003



Source: Statistics Canada, Farm Financial Survey, various years.

Figure 1.2 Capital Investments per Farm in Alberta 1991-2003



Source: Statistics Canada, Farm Financial Survey, various years.

Chapter 2: Review of Capital Budgeting Methods, Real Options Theory, and Methods for Calculating Real Options in Literature

This chapter reviews the definitions of capital investment and capital budgeting. The traditional capital budgeting method, Net Present Value, and its limitations in application are briefly discussed. Then the real options theory is introduced. Finally, different types of real options are introduced followed by a literature review of the standard methods used to calculate real options inherent in different sectors of agriculture.

2.1 Investment Decision and Capital Budgeting Methods

An investment is defined as an outlay of cash in exchange for expected future cash returns (Robison and Barry, 1996). Most investment decisions are often partially irreversible and competing for limited funds with other present and future opportunities. Therefore, a budget is needed as a detailed plan of cash returns and expenses expected over a certain period of time to provide guidelines for managing future investments and expenses. It was reported in the Western Canadian Benchmark Survey that more than two-thirds of the Alberta farmers/ranchers included budgets in their business plans as a means of aiding farm financial decisions (Alberta Agriculture, Food and Rural Development, 1999). Based on this survey result, it is inferred that most farmers tend to use budgets to guide their investment decisions rather than make decisions intuitively.

Olson (2004) distinguishes the decision to invest in capital assets such as land, buildings, and machinery from that used to buy seeds, fertilizer, feed and other operating inputs by pointing out that the result of purchasing seeds or feed is received within each production period, but the cash returns from capital assets occur over several periods. Consequently, cow/calf operations in this research are considered capital intensive enterprises because they require large initial capital investments in breeding stocks besides land, buildings, and machinery for future returns during their long life spans (Lawrence, 2000).

The investment in the operating inputs may only require simple and straightforward budgets to project if the purchase is worthwhile. But in order to determine whether a capital asset is a wise investment, farm managers should do capital budgeting which is the analytical process of evaluating and selecting capital investments (Brigham and Gapenski, 1997). All levels of investment planning from investment decisions of large business corporations to farm machinery replacement decisions can apply the capital budgeting methods.

There are several capital budgeting methods to evaluate a potential investment. The well-accepted and widely taught method is the Net Present Value (NPV) which summarizes the expected net cash flow produced by the investment into a single number that is adjusted for risk, inflation and the time value of money. Other types of conventional capital budgeting techniques used at the farm level are projected cash flow (Barnard, 1986), payback period, and internal rate of return (IRR) (Barry et al., 1988; Robison and Barry, 1996).

2.1.1 Net Present Value

The Net Present Value (NPV), as the most common technique recommended for use in capital budgeting, is the sum of the present values of future net cash flows minus the initial investment (Barry et al., 1988). The NPV method directly accounts for the timing and magnitude of the projected cash flows. By converting future cash flows to their present cash equivalent, NPV provides decision makers with the particular information needed to make investment decisions. The NPV criteria is to accept any investment if NPV > 0 when it is evaluated at the risk adjusted discount rate and to reject investment with a negative NPV. When NPV equals zero, theoretically speaking, investors are indifferent between accept and reject. As farm capital is often limited, investments may also be ranked on the basis of NPV. The ranking is made by comparing different combinations of potential investments for the highest total NPV. Mathematically, the NPV method is expressed as (Robison and Barry, 1996):

$$NPV = \sum_{t=0}^{n}\left[\frac{1}{(1+r)^t}\right] \times Y_t = Y_0 + Y_1\left[\frac{1}{(1+r)^1}\right] + \ldots Y_n\left[\frac{1}{(1+r)^n}\right] \quad (2.1)$$

where NPV = net present value, r = discount rate, Y_0 = the initial investment (as a negative amount), and Y_t = estimated net cash flow in period t.

The above NPV model assumes that all future cash flows can be discounted by the same discount rate. This assumption may be too restrictive for some projects. However, discount rates that vary from time to time can be easily accommodated into the model as well as cash flows with more than one change in sign (Robison and Barry, 1996).

In making an investment decision using the NPV model, four general steps are involved (Brigham and Gapenski, 1997; Olson, 2004). First, forecasts are needed to come up with the incremental future cash flows over the relevant time horizon if the investment project is accepted. Second, an estimation of the appropriate risk adjusted discount rate should be established and used for the calculation of the present value of the expected future cash flows. Third, the NPV is calculated from the cost of the investment and the present value of uncertain future cash flows generated by the project. Finally, a decision is made on whether the investment project is accepted or rejected.

2.1.2 Usages of Capital Budgeting Methods at the Farm Level

Graham and Harvey (2001) conducted a study examining the capital budgeting techniques used by large Fortune 500 firms. Based on their findings, 75 percent of these firms almost always used net present value or internal rate of return for measuring the desirability of capital budgeting decisions. In agricultural economics literature, there have been extensive and diverse applications of present value model to assess capital investments such as farm facility expansion and equipment replacement (e.g. Robison and Barry, 1996). However, research has concluded that farms may be using less advanced capital budgeting techniques than large Fortune 500 firms (Arthurton et al., 1995; Gloy and Ladue, 2003).

While a great deal of research has been done to identify appropriate investment analysis techniques and approaches, few studies have considered the adoption of these techniques at the farm level (Gloy and Ladue, 2003). The recent survey done by Gloy and Ladue in year 2003 examined the financial management practices of 92 New York dairy farms. The sample capital budgeting methods listed in the survey were the payback period, projected cash flow and a discounted cash flow technique such as net present value or internal rate of return. The types of investment decisions were: a facility expansion, an equipment replacement, and an increase in herd size. The projected cash flow was the most commonly used method (75%) for facility expansion, payback period was used by at least 40% of the respondents to evaluate all of the investments, and the use of net present value was the smallest proportion (8%). This lack of application of discounted cash flow analysis may be due to the level of numerical sophistication required to employ NPV.

Arthurton et al. (1995) reported the results on a study of the capital budgeting procedures considered ideal by managers in the greenhouse industry in Massachusetts. The payback criterion (PBK) was the preferred method identified by more than two-thirds of the respondents (111 greenhouse operators).

Although there is only a small portion of producers use the NPV model at the farm level, emphasis will still be placed on the NPV model in this chapter. NPV has some superior attributes. First, NPV uses all cash flows from the whole life of the investment to avoid ignoring any cash flows after a specific period (such as payback period does). NPV also accounts for the time value of money by discounting each cash flow (Ross et al., 2002). Finally, cash flows that reverse signs in an NPV model do not generally invalidate the NPV model as a tool for comparing and selecting among the alternative investments, whereas such cash flows do create serious problems in the IRR model (Robison and Barry, 1996).

For these reasons, NPV is the recommended approach for investment analysis and it is comparatively easy to use (Trigeorgis, 1999). An increasingly widespread use of NPV model in large sized firms has been suggested by survey results. Economists have encouraged farmers to evaluate investments using the NPV approach. In agricultural economics literature, NPV has been used as the principal

criteria for many durable productive asset replacement decisions. In the cattle industry, specifically looking at cows and heifers as potentially productive assets, several studies that have addressed the NPV application in optimal cow replacement decisions (Trapp, 1986; Mathews and Short, 2001; Ibendahl et al., 2004) are discussed later.

2.1.3 Limitations of the Net Present Value

In order to use the NPV approach, there should be appropriate procedures to estimate the unique discount rates at which future cash flows from the investment projects are discounted. Weldon and Moss (1994), in their NPV study, presented a method of estimating future non-constant risk adjusted discount rate for net present value based on the theory of the term structure of the interest rates. They concluded that failure to adjust the cost of capital implied by the discount rate when term structure was upward or downward sloping would result in biased NPV in capital budgeting decisions. Reid and Bradford (1987), in their farm machinery investment decision study, argued that the cost of capital approach (risk adjusted discount rate[5]) might be a possible way of incorporating risk. But even if the cost of capital for each production activity and machinery investment was known, modeling the appropriate cost of capital for the whole farm might be difficult unless all projects of the farm were of the same risk class.

Aggarwal (1993) pointed out that NPV and other traditional capital budgeting procedures had generally ignored the valuation of options created by an investment when the conditions of irreversibility and uncertainty are present. Collins and Hanf (1998) concluded that failure to consider the possible irreversibility of farm investment decisions and the option to postpone decisions until more information was available could be one major source of considerable bias in NPV and lead to incorrect decisions. In Baldwin (1982)'s study, he suggested that under the condition of limited funds, when sequential irreversible investment opportunities arrived at random, the NPV rule led to overinvestment. In contrast, for cases where initial investment can provide information that reduces uncertainty in the future value of a project, the NPV

[5] The methods of determining the risk adjusted discount rate are discussed in Appendix A.

may undervalue the investment project and it may be appropriate to undertake investments with a negative NPV (Roberts and Weitzman, 1981).

More recently, many academics and practicing managers have recognized that the net present value and other discounted cash flow approaches do not capture manager's flexibility to adapt and revise later decisions in response to unexpected market development (McDonald and Seigel, 1986; Dixit and Pindyck, 1994; Trigeorgis, 1995). More specifically, the standard net present value model assumes a fixed scenario in which an investor starts and completes a project and generates expected cash flows, without permitting the uncertainty of returns to influence the adoption decision. However, as new information arrives, management may have valuable flexibility to alter its operating strategy, especially when flexibility is reduced by capital-intensive and specialized investments whose effects would last for several years.

Real options, is an emerging model based on financial option principles for investment decision that attempts to capture the value of managerial flexibility. A traditional capital budgeting method generally treats projects as isolated investment opportunities about which only an accept/reject decision must be made to start/give up the investment. But oftentimes, firms invest to enter a new market not so much because the immediate investments have a positive NPV, but rather because it positions firms advantageously in the market and create options for valuable follow-up opportunities (Aggarwal, 1993). The future assets created by this initial investment can not be adequately captured by traditional capital budgeting methods. However, an option based capital budgeting approach may properly qualify a capital investment with uncertain returns as an ongoing process and capture the managerial flexibility in active decision making (Lai and Trigeorgis, 1995). It is the purpose of this study to explore the applicability of real options as a potential capital budgeting procedure in agricultural investment, particularly in the beef cattle industry.

2.2 Real Options Theory

Real options theory applies financial options theory to value managers' flexibility in adapting their future actions (e.g., deferring, expanding, contracting,

switching or abandoning) in response to evolving market or technological conditions (Copeland and Antikarov, 2001). Such flexibility in real investment projects has long been recognized and intuitively desired by managers. However, not until the publication of the Nobel Prize-winning work of Fischer Black and Myron Scholes (1973), and Robert Merton (1973) on the pricing of financial options and Stewart Myers' (1977) pioneering idea of viewing firms' discretionary future investment opportunities as real or non financial options, had there been formal models to incorporate such flexibility.

The following sections provide a brief overview of the financial (stock) options followed by a discussion on real options theory and the real option valuation methods. The main purpose of the review and the discussion is to extract the key principles appropriate for the cattle industry and to provide context for determining the appropriate valuation methods, especially when there are multiple sources of risk.

2.2.1 Overview of Financial Options

A financial option gives the holder the right, but not the obligation, to buy or sell a designated asset (e.g., common stock) at a predetermined price on or before a specific date (Hull, 2002). In financial terminology, the predetermined price is called the exercise price and the specific date is the expiry date or maturity date. The money investors pay for the option is known as the option premium.

A call option gives the holder the right to buy the underlying asset at a fixed price (exercise price) on or before the expiry date of the option. At expiration, the option holder would exercise the option if the value of the asset is above the exercise price of the option and not if it is below. If we use S to denote the value of the asset and X the exercise price (strike price), then at expiry the option is worth

$$\max(S-X,0) \tag{2.2}$$

This function of the underlying asset is called the payoff function. The put option gives the holder the right to sell the underlying asset at a fixed price (exercise price) on or before the expiry date of the option. If the value of the asset is below the exercise price, the option is exercised. The option will expire worthless if the value of the asset is above the exercise price. The payoff function for a put option is

$$\max(X - S, 0) \tag{2.3}$$

According to the exercise features, financial options can generally be divided into two different kinds. A European option can only be exercised on expiration date. An American option can be exercised at any time up to the expiration date. This added freedom of American option makes the American option more valuable than the similar European option especially when the underlying asset pays a dividend. On the flip side, American options are more difficult to value (Hull, 2002). There is also a non-standard American option that the option is most likely to be exercised at some specific time points prior to the expiration. This form of exercise pattern is known as Bermudan exercise. The name was chosen because Bermuda is half way between America and Europe (Wilmott, 2001 pp. 44).

The value of an option depends on five basic variables plus a very important six (Copeland and Antikarov, 2001). They are:

1. *The value of the underlying risky asset.* The underlying asset for a financial option is a security such as a share of common stock or a bond. The value of the risky asset is the present value of the expected cash flows to be received from the asset. An increase in the present value of the underlying asset will increase the value of the call option but decrease the value of the put option.
2. *The exercise price.* This is the present value of the expenditures required to acquire the underlying asset with a call option, or the present value of capital gains from exercising a put option. As the exercise price of an option increases, the value of the call option decreases, and the value of the put increases.
3. *The time to maturity or expiry date of the option.* It is the length of time the option cease to give the holder the rights. As the time to maturity goes up, the value of the option usually increases.
4. *The volatility of the value of the underlying asset.* It is a measure of the amount of future movements of the asset price; a measure of randomness. Generally the value of an option increases with the volatility of the underlying asset. The payoff of a (call) option is the amount of the value of the underlying asset exceeding its exercise price. When the volatility of the

underlying asset increases, the probability of getting a positive payoff also increases. Hence, this raises the value of the option which depends on the payoff.

5. *The risk-free rate of interest over the life of the option.* The risk-free rate gives the time value of money. As the risk-free rate goes up, the value of the call option increases while the value of the put option decreases.
6. *Dividends.* That is the payout by the underlying asset in the form of explicit cash flows. Because the stock price is expected to drop by the amount of the dividend on the ex-dividend date, high cash dividends imply lower call premiums and higher put premiums.

As indicated at the beginning of this section, the real options theory is based on financial option principles. Next section explores the characteristics of the real options.

2.2.2 Definition of Real Options

Similar to financial options, real options allow the management of a firm to have the right, but not the obligation, to take an action (e.g., deferring, abandoning, expanding, contracting, etc.) at a predetermined cost (Copeland and Antikarov, 2001). The underlying asset for a financial option is a security, while the underlying for a real option is a tangible asset, for example, a business unit, an investment or a project. Another important difference between financial and real options is that the value of the underlying (e.g., a share of a common stock) will not be affected by the people who own the financial option on it. But the value of a real asset or a project can be raised by the actions of the management who makes use of the real options.

Unlike the other traditional capital budgeting procedures, which require unchanged management of an investment after the initial accept/reject decision, real options approach provides a framework to analyze strategic capital investments by enabling investments to be treated as opportunities rather than now or never type of investment decisions (Dixit and Pindyck, 1994). For example, a corporate investment opportunity is like a call option because the corporation has the right, but not the obligation, to acquire the operating assets of a new investment (Luehrman, 1998).

Like the financial options, the value of the simplest real options depends on six basic variables (characteristics of a business opportunity). The correspondence between the project's characteristics and the variables that determine the value of a simple real call option is illustrated by mapping the characteristics of the business opportunity and managerial actions onto the template of a call option in Table 2.1. Although the call option in this illustration is a simple European option, which is not a perfect substitute for the real opportunity, it is still informative and adapted by Luehrman (1998), Copeland and Antikarov (2001), and Remer et al. (2001).

2.2.3 Irreversibility, Postponability, and Uncertainty

Not all investment decisions are appropriate to be analyzed under a real options framework. Traditional tools work well when there are no options at all, or there are options but very little uncertainty (Amram and Kulatilaka, 1999). Although uncertainty is everywhere, the consequences of uncertainty for some projects are sufficiently small that they can be ignored. A real options analysis is needed under conditions of irreversibility, postponability, and uncertainty (Dixit and Pindyck, 1994).

Irreversibility means the investment expenditures are mostly sunk costs[6] that can not be recovered. Irreversibility makes investment especially sensitive to various forms of risk, such as risks over the future product prices and operating costs that determine cash flows. In the farming situation, investments in specialized farm buildings are particularly irreversible (Collins and Hanf, 1998). Specialized farm buildings such as dairy barns and milking parlors cannot be easily utilized for other productive activities than the one on which they were originally constructed. Hence the market value of such buildings is very low if they are not used for their original purpose. Similarly, this is also true for investments in buildings and facilities in cow/calf farms, backgrounding operations, and feedlots. These costs may be considered as sunk costs.

[6] Usually when capital is industry specific and can not be used productively by a different industry, it is a sunk cost and thus irreversible.

The second condition, feasibility of postponing the decision is usually fulfilled in the cattle industry (Munro, 1993). In Munro's retained ownership study, he suggested that for many farms, the decision to sell calves that were born in spring could be postponed to gather further market evidence. For an individual farm, the postponability would depend, in part, on the cash flow requirements and the capital structure of the farm. Also postponability may be limited by the timeline of production systems when dealing directly with live cattle. For the purpose of this study, we assume that producers in the three sectors of the cattle industry have sufficient financial means to postpone the decision.

As for the uncertainty, it is easy to see that the cattle market is uncertain and that future returns from feeding or selling calves are difficult to predict (Munro, 1993). In order to be more specific, Olson (2004) identified six primary sources of agricultural risk that affect producers' return: production risk, market risk (price risk), institutional risk, human risk, business risk, and financial risk.

The types of risk that affect the returns to beef cattle operations most are identified by cattle producers and ranchers. In the survey performed by Texas and Kansas Risk Management Education Teams in 1996, U.S. producers and ranchers ranked twenty-one sources of risk that affect income on a 5-point scale. The ten most important sources of risk as indicated by their average ratings are reported in Table 2.2. Market risk (rank 1) and production risk (rank 2) were the biggest factors affecting income. This result was supported by a more recent survey about beef producers' perceptions of risk sources done by the National Agricultural Statistical Service (NASS) in 2000 (Hall et al., 2003). According to the survey result, the U.S. beef cattle producers are most concerned about price variability and risk factors affecting productivity. In beef cattle operations, production risk consists of unexpected changes in feed conversions, calf weaning rate, calf weight, feed cost, morbidity and mortality. Market risk is represented by the variability of returns due to changes in cash market price[7], future market price and basis level[8]. Since U.S. and Western Canada beef cattle producers share a lot of similarities, it can be inferred that

[7] Figure 2.1 demonstrates how cash market prices of cows and calves fluctuated over time.
[8] Basis is the difference between the current cash price of a commodity and the futures price of the same commodity.

production variability and price variability are the major sources of risk associated with cattle operations in the province of Alberta.

When an investment decision is irreversible and postponable under an uncertain environment, and waiting may improve the estimates of profitability, the decision based on the present value of the project obtained with current information should be reconsidered to account for the option value (Collins and Hanf, 1998). Theoretically, real options approach has the potential to help in making the investment decisions in the cattle industry under risk and uncertainty.

2.2.4 Type of Real Options and an Example of Multistage Investment

In practice, many investments can either be undertaken immediately or be put off until a later period when there may be better information about the payoff. In other words, decision makers may not have to choose between the two alternatives, "invest" or "do not invest". In many cases they are confronted with a third alternative: "wait and then decide" (Collins and Hanf, 1998, pp. 86). And once a large capital investment is undertaken over a long span of time, it may well contain projects that can be undertaken, altered, or abandon at various points in time (Kester, 1993). Following Trigeorgis' (1996) example of multistage decisions of an oil company which plans to drill on undeveloped land with potential oil, the farrow-to-finish pork project analyzed by Duku-Kaakyire (2003) can be used to map different categories of investments into the space of different types of options.

A large tract of land is to be purchased for the purpose of starting a 2600 farrow-to-finish pork operation. Before the purchase of land, feasibility studies such as water testing and regulatory building approval are carried out. The cost of feasibility studies will be followed by the cost to purchase the land, I_1. This would be followed by outlays for the construction of the barns, I_2. Breeding animals can only be purchased after construction is completed. So cash inflows are only generated during the "operating stage" that follows the last outlay. During construction, if market conditions deteriorate, the owner of the land can choose to forgo any future planned outlays. The owner may also choose to reduce the scale of the operation by c%, saving a portion of the last outlay, I_C, or shut down the operation temporarily. If

the value of the project turns out to be higher than expected, the scale of production can be enhanced by x% , with a follow-up outlay of I_E. It is assumed that at any time, the owner can salvage a portion of the investment by selling the equipment and land for their salvage value A. This project presents the following collection of real options:

i. *The option to defer investment.* It occurs when a decision can be put off until some date in the future. In the example, the feasibility studies enable the investor to defer the purchasing of land and benefit from the resolution of uncertainty about pork prices during this period. The land would be bought immediately only if the expected NPV is sufficiently high. At the end of the feasibility tests, the value created will be $\max(V - I_1, 0)$ where V is the gross present value of the completed project's expected operating cash flows[9]. The option to defer is thus analogous to an American call option with the exercise price being equal to the cost of land, I_1. Once an early investment is made, the option to defer is forgone. This option value loss is like an additional investment opportunity cost. It requires the value of cash benefit, V, to exceed the initial outlay by a substantial premium.

ii. *The sequential compound option.* The initial capital investment in the farrow-to-finish pork project occurs in two different stages which must be carried out in sequence. The first stage involves the purchase of land after feasibility tests and the second stage involves building the barns and purchasing the breeding animals. Thus, each stage can be viewed as compound options which are options whose value is contingent on the value of other options (Copeland and Antikarov, 2001). A real options approach treats a series of compound options that occur in sequence as a sequential compound option. It enables managerial flexibility in multistage decision making by creating valuable options to "default" at any given stage.

iii. *The option to expand.* If the project value turns out to be more favorable than expected, the owner can expand the scale of production (by x%) by

[9] However, in sequential compound options, *V* represents the option value on which the sequential compound option value is contingent.

incurring a follow-up cost outlay, I_E. This is similar to a call option to acquire additional buildings and breeding animals (x%) of the base-scale project, paying I_E as exercise price. The investment opportunity with the option to expand can be viewed as the base-scale project plus a call option on the future investment, $V + \max(xV - I_E, 0)$.

iv. *The option to contract.* If market conditions are worse than originally expected and result in a decrease in project value, the owner can operate below capacity or even reduce the number of the breeding animals (by c%), thereby saving part of the planned investment outlays, I_C. This flexibility to mitigate loss can be valued as an American put option on part (c%) of the base-scale project, with exercise price equal to the potential cost savings, I_C, giving $\max(I_C - cV, 0)$.

v. *The option to temporarily shutdown and restart.* If the cash revenues of the operation are insufficient to cover various operating costs in the short term, it might be better to shut down the operation temporarily. Once cash revenues are expected to rise sufficiently, the operation can start again. The operation in each year can provide annual cash revenues V_0. The option to restart can be seen as a call option to acquire V_0 by expending the operation cost I_0 as exercise price, $\max(V_0 - I_0, 0)$. The option to temporarily shutdown and restart is especially valuable if the costs of switching between operation and inactive modes are low.

vi. *The option to abandon for salvage value.* If pork prices suffer a persistent decline that cannot provide sufficient revenues to cover costs, the owner is assumed to have a valuable option to abandon the project permanently in exchange for the salvage value though the specialized farm assets in a pork barn do not seem to have a high salvage and option abandonment value. This option is analogous to an American put option on current project value (V) with exercise price being equal to the salvage value (A), giving the owner $\max(A - V, 0)$.

There are other types of real options that could exist such as the option to switch use[10], etc. However, these options are likely to have very limited applicability in a typical agricultural investment (i.e., option to switch use exists in industries which can be designed to use alternative forms of inputs to convert the original output into a variety of other output products). The above example with its collection of real options is summarized in Figure 2.2.

2.3 Methods for Calculating Real Options in Literature

Although, initially real options had been analyzed in the cases of mining operations and natural resource investment (McDonald and Siegel, 1985; Brennan and Schwartz, 1985), a growing stream of literature using real options approach in capital budgeting in a range of other areas has emerged in recent years. Several basic methods appearing in agricultural economics literature are discussed below.

2.3.1 Dixit and Pindyck Model

Dixit and Pindyck (1994) argued that if an investment decision is irreversible, once the decision to invest is made, the option of making the decision at a later time is foregone. This option of waiting to decide has value when additional information about the payoff of the project is expected in the future. Therefore, consideration of the possibility of waiting to invest may have an important impact on investment decisions. Purvis et al. (1995) first applied the Dixit-Pindyck single discrete investment model to analyze dairy producers' decision to invest in free-stall dairy housing. The value of investing in free-stall dairy housing, V, evolves as geometric Brownian motion (GBM):

$$dV = \mu V dt + \sigma V dz \tag{2.4}$$

where μ is the drift rate, σ the standard deviation of the log expected returns from the investment, and dz the increment of a Wiener process, i.e., $dz = \varepsilon_t \sqrt{\Delta t}$ where ε_t is N(0,1). The value of investment opportunities (the value of option to invest) denoted

[10] However, options to switch from backgrounding to feedlot provide viable alternatives at a certain weight range of feeder cattle.

by F(V), is the solution to the following partial differential equation and some boundary conditions[11].

$$\frac{1}{2}\sigma^2 V^2 F''(V)dt + \mu V F'(V)dt - rFdt = 0 \qquad (2.5)$$

where V is the value of investing in free-stall dairy housing, μ the drift rate, σ^2 the variance of the log expected returns from the investment, $F'(V)$, $F''(V)$ the first and second derivative of the value of option to invest, respectively, and r the risk adjusted discount rate. Dixit and Pindyck (1994) demonstrated the optimal investment rule using dynamic programming.

Both a modified hurdle[12] rate and an optimal investment trigger which takes account of uncertainty and irreversibility were found to be significantly higher than those under a present value criterion. The NPV of investing in free-stall dairy housing should be large enough to provide a much higher return above the required rate of return implied by the original hurdle rate to compensate the forgone value of waiting for better information.

Jeffery et al. (2003) applied the Dixit and Pindyck theoretical model to the decision of replacing an existing milk parlor with an automatic milking system. By converting the present value of the net benefit into a perpetual annuity V_n, a higher trigger value was generated under real options rule than the traditional NPV rule.

Price and Wetzstein (1999) extended Dixit and Pindyck's model to include both price variability and yield variability in Georgia peach production and measured the optimal entry and exit thresholds. Revenue was modeled as the product of two geometric Brownian motions, price and yield (output), respectively. Since Dixit and Pindyck generally examine entry and exit conditions for a firm when only output price is uncertain and follows a GBM, output is assumed non-stochastic. However, in many instances a deterministic future output level is unrealistic. This is especially

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[11] It is derived from the Bellman equation by applying Ito's Lemma. Interested readers please see Dixit and Pindyck, *Investment under Uncertainty*, (1994, Ch. 5).

[12] The modified hurdle rate incorporates a correction for the forgone value of option to wait (Dixit, 1992).

true in agriculture, while the inability to completely control environmental conditions contributes to the stochastic nature of yield.

Other studies using Dixit and Pindyck's dynamic programming and general numerical solution technique to value the real options include: Richards and Patterson (1998) assessed the problem of agricultural labor shortage by estimating the real options value implicitly in a worker's decision and wage expectation to seek employment in either the agricultural or non-agricultural sector. Isik et al. (2001) analyzed the adoption of interrelated technologies when fixed cost can generate option values to delay the investment and some components of the technological package in site-specific crop management. Insley (2002) modeled the optimal tree harvesting decision when lumber prices were assumed to follow some known stochastic processes.

Limitations of the Dixit and Pindyck Model

Dixit and Pindyck's model is among the best analytical models in quantifying various types of real options separately and in combination. The model result can be directly implemented in the strategic aspects of investment under uncertainty. There exist a number of limitations in applying the model.

First, the Dixit and Pindyck model relies on a simplifying assumption of an infinite utilization horizon which makes the investment opportunity analogous to a perpetual call option with an infinite expiry date (Collins and Hanf, 1998). Although such simplification is helpful to ease the calculation, it can be criticized from both a theoretical and a practical viewpoint. Because the real investment project pays dividend (revenue flows), exercise before the expiry date can be optimal (Dixit, 1992). The option value found using a perpetual option framework is often larger than the option value of real investment in finite time, because investors in an infinitely lived perpetual project can take advantage of the longer time interval to capitalize on the future resolution of the uncertainty (Maung and Foster, 2002). Grenadier (2002) argued the value of the "option to wait" which led firm to invest only at large positive net present value would be eroded very quickly by factors such as competition in many real world markets.

Second, Dixit (1992) made an assumption of a zero drift rate (rate of growth of V) for expository simplicity in his single discrete investment example. However, in agriculture, expectation of capital appreciation is an important determinant in valuing capital investment (Bauer, 1983). The earnings of a farm business are heavily influenced by gains or losses in the value of asset (Gloy and LaDue, 2003). Including changes in the value of farm assets can affect the option value. With an expected growth rate of capital gains, the investment will be more attractive. The value of avoiding a given amount of downside risk in the investment becomes more valuable. So does the value of waiting with the investment (Dixit, 1992) [13]. Thus, an assumption of a zero drift rate may understate the value of option to wait associated with the investment opportunity. So when adapting the Dixit and Pindyck's discrete investment model in analyzing the value of waiting in real agricultural investment projects, changes in the value of the assets should be included.

Finally, the Dixit-Pindyck model is somewhat mathematically intensive. When multiple sources of risk are involved, the computational complexity of the Dixit and Pindyck model increases rapidly (Amram and Kulatilaka, 1999). This may make it hard to use.

2.3.2 Black-Scholes Model

Another analytical option valuation model commonly used in addressing real options in agricultural investment decision is the Black-Scholes model. The Black-Scholes equation is the most commonly used formula for determining the value of a European financial option. The model for calculating a call option, *c* is given as (Hull, 2002):

$$c = VN(d_1) - Ie^{-rT}N(d_2) \tag{2.6}$$

where

$$d_1 = \frac{\ln(V/I) + (r + \sigma^2/2)T}{\sigma\sqrt{T}} \tag{2.7}$$

$$d_2 = d_1 - \sigma\sqrt{T} \tag{2.8}$$

[13] Interested readers please see Dixit (1992) pp. 117 for details.

V = the gross present value of the underlying asset

I = the initial capital cost or the strike price

T = time to maturity

R = the risk free rate of return

σ = the volatility of rate of the return of the underlying asset

$N(\cdot)$ = the cumulative standard normal density function

Ehmke et al. (2004) valued the real options an average farmer in central Northern Dakota holds for the investment decision of entering the organic Durum wheat and barley market now versus a future date. The option value was calculated from a table developed by Luehrman (1998) which shows the corresponding Black-Scholes value of a European call option for each NPVq[14] and cumulative volatility. Briggeman, Detre, and Gray (2004) used a slightly adjusted Black-Scholes model to capture the option to defer associated with the entry of a new GMO juice product into the market.

Limitations of the Black-Scholes Model

Although the Black-Scholes formula is often used to illustrate the analogies of financial and real options, limitations of modeling real options via the Black-Scholes model are evident in the underlying assumptions of the Black-Scholes model. First, it assumes the option can only be exercised at maturity (European options). Thus, it cannot be used to value any American-type options. But most of the real options can be exercised at any time within the life of the investment opportunity when new information comes in. So the European option is not a good substitute of real opportunities (Luehrman, 1998). Second, the original Black-Scholes model assumes a single underlying risky asset, thus compound options which are embedded in most real life investment decisions can not be easily valued. Although it is possible to find analytical formulas for the price of basic compound options in the Black-Scholes framework, these formulas are very sensitive to the basic pricing model of the high order option and should be used with caution in practice (Wilmott, 2001). Third, there

[14] q is the ratio calculated by dividing the present value of the project (V) by the present value of the exercise price (PV(X)).

is only one source of risk stated in the model assumption, while most real life investment projects have multiple sources of risk.

2.3.3 Multiplicative and Three-Dimensional Binomial Models

Cox, Ross and Rubinstein (1979) developed the binomial option pricing model which approximated the behavior of an asset price by the upward and downward changes in the asset price over a particular interval of time. The multiplicative binomial model is a form of the explicit finite difference approach with a large number of time steps and is based on the risk-neutral approach (Wilmott, 2001). It is one of the most widely used numerical models to price options (Schwartz and Trigeorgis, 2001).

A given project value (or stock price, V) may evolve into one of two probabilistic prices, which allows the underlying asset to move up with probability p or down with probability 1-p by a prescribed amount over the next time step Δt (up move by u and down move by d). Figure 2.3 demonstrates a binomial tree of the project value after two time steps. The up and down ratios as well as the probability p, can be calculated using the following equations (Hull, 2002):

$$u = e^{\sigma\sqrt{\Delta t}} \tag{2.9}$$

$$d = e^{-\sigma\sqrt{\Delta t}} \tag{2.10}$$

$$p = \frac{e^{(r-\delta)\Delta t} - d}{u - d} \tag{2.11}$$

where σ is the volatility rate of the project, δ is the dividend payout ratio of the project.

This lattice structure in Figure 2.3 is extending out all the way to expiry. After constructing the tree of project values, the valuation of options can be worked out by applying the concept that the value of a project is its risk-neutral expectation of discounted payoffs. The computational efficiency is generated by jumping backwards over time from the final vector of project value (and thus option prices) to the initial option value (Geske and Shastri, 2001). In Figure 2.3, consider an American call option with two time steps. On the expiration date, depending on the project value, the option value will be:

$$C(Vuu) = \max\{\ 0,\ Vuu - X\ \}$$

$$C(Vud) = \max\{\ 0,\ Vud - X\ \}$$

$$C(Vdd) = \max\{\ 0,\ Vdd - X\ \}$$

Working backwards by one timestep,

$$C(Vu) = \max\{\ Vu - X,\ [p \times C(Vuu) + (1-p) \times C(Vud)]\ e^{-r\Delta t}\ \}$$

$$C(Vd) = \max\{\ Vd - X,\ [p \times C(Vud) + (1-p) \times C(Vdd)]\ e^{-r\Delta t}\ \}$$

Finally, working backwards to the beginning of the tree and the call option value is:

$$C(V) = \max\{\ V - X,\ [p \times C(Vu) + (1-p) \times C(Vd)]\ e^{-r\Delta t}\ \}$$

The binomial model with its flexible structure is capable of pricing both American options by checking at every node in an option's life the possibility of early exercise and compound options by its working back calculation.

In dealing with underlying payoffs that depend on two risky assets, such as the spread option[15], the three-dimensional binomial model was introduced by Rubinstein (1994). The idea is to combine two binomial trees into a three-dimensional space as illustrated in Figure 2.4 to get the option value based on two correlated assets. Examples of spread option are found in oil and power products. The New York Mercantile Exchange (NYMEX) has two exchange-traded versions of spread options, crack spread options and spark spread options (Leppard, 2002). Crack spread options have the payoff on the difference between crude oil futures and either heating oil or unleaded gasoline futures prices. The payoff of a crack spread call is $Q[\max(\tilde{P}_{refined} - \tilde{P}_{crude} - X, 0)]$ where Q denotes the units, X the conversion cost, and "~" represents a stochastic process. This option also has American exercise features. Spark spread options pay off the difference between forward price of electricity and the (heat rate adjusted) forward price of natural gas. A typical spark spread option payoff equals $Q[\max(\tilde{P}_{power} - h\tilde{P}_{gas} - X, 0)]$, where h denotes the heat rate. Spread options are also traded in agricultural futures markets. The crush spread, also known as the soybean complex spread, is traded on the Chicago Board of Trade (CBOT). The underlying indexes comprise futures contracts of soybean, soybean oil, and

[15] A spread is defined as the numerical difference between the prices of two future contracts or two products.

soybean meal where the unrefined input is the soybean, and the outputs are soybean meal and oil. The crush spread is defined as the value of meal and oil extracted from a bushel of soybeans minus the price of a bushel of soybeans. The crush spread gives market participants an indication of the average gross processing margin.

The underlying assets in the spread option payoff are defined as S_1 for the first and S_2 for the second asset. Regardless of the stochastic processes (e.g. mean reversion[16]) of multiple correlated sources of cash flows that a productive asset is expected to have, the changes in its combined present value may follow a random walk (Copeland and Antikarov, 2001). Therefore, S_1 and S_2 are assumed to follow geometric Brownian motions such that[17]:

$$dS_i = \mu_i S_i dt + \sigma_i S_i dz_i \; ; \; i = 1,2 \tag{2.12}$$

where S is the real asset value which represents the i th uncertain asset, μ is the drift rate, σ the standard deviation of the log expected returns from the assets, and dz the increment of a Wiener process, i.e., $dz = \varepsilon_t \sqrt{\Delta t}$ where ε_t is N(0,1). The correlation between the first and second Brownian Motions is assumed to be ρ so that

$$E[dz_1 dz_2] = \rho \, dt \tag{2.13}$$

where E[·] represents an expectation.

During the first move, the first asset return is assumed to move up to u from the node (S_1, S_2),

$$u = \exp(\mu_1 \Delta t + \sigma_1 \sqrt{\Delta t}) \tag{2.14}$$

where Δt is the elapsed time per move; or down to d from the node (S_1, S_2), while the probabilities of moving up and down are set equal (Rubinstein, 1994).

$$d = \exp(\mu_1 \Delta t - \sigma_1 \sqrt{\Delta t}) \tag{2.15}$$

Simultaneously, if the first asset moves up to u, then returns from the second asset can move to A or B, with equal probability; or if the first asset moves down to d,

---

[16] Mean reversion is a tendency for a stochastic process to remain near, or return over time to a long-run average.

[17] The risk-neutral dynamics of the values of the real assets are given by correlated geometric Brownian motions $dS = bSdt + \sigma Sdz$. The logarithm of the real asset gives $G = \ln S$. By using Ito's lemma, $dG = (b - 1/2\,\sigma^2)dt + \sigma dz$. The volatility of the asset is equal to the standard deviation of the continuous return provided by the real asset in one year.

then the second asset has returns either C or D, with equal probability. It is assumed that the second asset returns are chosen so that AD = BC. So starting at (S_1, S_2), there is a ¼ chance of moving to each of the following $(S_1 u, S_2 A)$, $(S_1 u, S_2 B)$, $(S_1 d, S_2 C)$ or $(S_1 d, S_2 D)$.

where
$$A = \exp[\mu_2 \Delta t + \sigma_2 \sqrt{\Delta t}(\rho + \sqrt{1-\rho^2})] \quad (2.16)$$

$$B = \exp[\mu_2 \Delta t + \sigma_2 \sqrt{\Delta t}(\rho - \sqrt{1-\rho^2})] \quad (2.17)$$

$$C = \exp[\mu_2 \Delta t - \sigma_2 \sqrt{\Delta t}(\rho - \sqrt{1-\rho^2})] \quad (2.18)$$

$$D = \exp[\mu_2 \Delta t - \sigma_2 \sqrt{\Delta t}(\rho + \sqrt{1-\rho^2})] \quad (2.19)$$

and
$$\mu_1 = b_1 - \sigma_1^2 / 2 \quad (2.20)$$

$$\mu_2 = b_2 - \sigma_2^2 / 2 \quad (2.21)$$

where ρ denotes the non-zero correlation between the returns of the two assets, b the cost of carry term and $b = r - \delta$, r denotes the risk-free rate and δ is the continuous dividend yield (Haug,1998).

During the second move, given that the first return was $(S_1 u, S_2 A)$, then the second return can again be either $(S_1 u, S_2 A)$, $(S_1 u, S_2 B)$, $(S_1 d, S_2 C)$ or $(S_1 d, S_2 D)$. Multiplied together the return of the asset over the first two moves is then either $(S_1 u^2, S_2 A^2)$, $(S_1 u^2, S_2 AB)$, $(S_1 ud, S_2 AC)$, or $(S_1 ud, S_2 AD)$, each with the equal probability ¼ × ¼ = 1/16 (Rubinstein, 1994). When the returns of the underlying assets are standardized to 1 for the first and 1 for the second asset, Figure 2.5 illustrates the three-dimensional binomial pyramids with one and two time steps starting from (1, 1).

Continuing in this same fashion, if the pyramid consists of n moves, then the total number of distinct nodes at the bottom would be $(1 + n)^2$. The payoff function of a spread option which depends on the spread between two risky assets is used at the bottom to jump backwards over time from the final pyramids of asset returns (and thus the option value) to the initial option value just like the multiplicative binomial model. In practice, this is naturally done in a computer based model.

Limitations of the Multiplicative Binomial Model

The multiplicative binomial model is often capable of valuing options with payoffs based on the value of one single underlying asset, both European and American. In cases where the payoff function involves two underlying assets with correlation, more complicated three-dimensional binomial model could be introduced. But the calculation of the three-dimensional binomial model is more burdensome than the multiplicative binomial model. Adding more risky assets to the payoff function can increase the complexity rapidly.

2.3.4 Monte Carlo Simulation

The valuation and optimal exercise of American options using simulation models particularly when more than one factor affects the value of the option remains one of the most challenging problems in derivative finance (Longstaff and Schwartz, 2001). In the past few years, numerical methods have been developed using simulation techniques to solve American-type options. Broadie and Glasserman (1997) designed a Monte Carlo method to value the American financial option that incorporated early exercise, multiple-state variables, multi-choice decisions and temporal optimality. Longstaff and Schwartz (2001) published a method to value American options by simulation. The algorithm was designed to determine the optimal exercise strategy of the American option by using least squares regressions. This technique is referred to as the least squares Monte Carlo (LSM) approach. Simulation models roll out thousands of possible path of evolution of the underlying asset from the present to the final decision date in the option with the power of modern computers. Adding a new source of risk to the simulation analysis is less burdensome in complexity of calculation than the other numerical approaches (Amram and Kulatilaka, 1999). And simulation models can handle complex exercise and payout contingencies.

Maung and Foster (2002) compared the option values under the two marketing alternatives (enter into market contracts or sell the hogs in the cash market) in the hog industry using the simulation method designed by Broadie and

Glasserman. Maung and Foster highlighted the fundamental way in which the option values changed in response to the duration of the contract and the initial price vector.

Limitations of the Monte Carlo Simulation

Monte Carlo simulation (MCS) can be used to approximate the stochastic process based on a sequence of random variables from a random number generator to produce discretely sampled paths of a continuous-time stochastic process (Seppi, 2002). But the procedure for the estimation of the interdependencies among variables is complex. Also, valuing American-type options via MCS by characterizing the optimal exercise boundary at each time interval can be very mathematically complicated. According to the LSM, a new functional form of the basis function must be chosen to incorporate a new source of risk in the simulation, which requires numerical expertise.

2.3.5 Gaps between Literature

The combined literature above suggests that real options analysis has been successfully applied to some investment decisions and observed problems in different agricultural operations. However, to date, few articles have been found that specifically address the use and application of real options in the cattle industry. For industries such as the commercial beef cattle industry which involves several distinct sectors as an integral production system, real options analysis should be broken down into each sector respectively. But research discussed above only value one option or one sequence of options embedded in a single agricultural project. Furthermore, while most of the research has focused on determining the option value in the investment using various option valuation models, few have further considered the real option implications for future investment policy in determining optimal investment /disinvestment thresholds and timings. As shown in the case study in Copeland and Antikarov (2001), the payoffs and exercise pattern of the American type of real option in binomial models can be translated into investment strategies for a multi-staged investment.

In this study, the major investment decisions within each sector are identified first. Then the real options associated with the investment decisions are classified.

Based on the different payoff patterns of the real options and sources of risk in the operation, option valuation methods are determined. The real option value and the implications for investment policy are calculated and analyzed.

2.4 Chapter Summary

This chapter reviews definitions of capital budgeting and Real Options (RO) approach. It first emphasizes the importance of capital budgeting methods in agricultural capital investments. Then deficiencies of the traditional capital budgeting method are explained. Next, the real options theory is introduced followed by the implication of the potential to use RO in agricultural investments. Finally literature regarding different valuation approaches in applying RO to agricultural investments is discussed. The literature describes four main methods that can be used to calculate RO including the Dixit and Pindyck model, the Black-Scholes Model, the multiplicative and three-dimensional binomial model and the Monte Carlo simulation. For the purposes of this research, we should not limit ourselves to the numerical methods discussed above. It is important to understand the idea of analyzing investment opportunities as real options and to fit the individual investment project into the appropriate option valuation scheme.

2.5 Tables for Chapter 2

Table 2.1 Mapping an Investment Opportunity onto a Call Option

Variable	Financial option	Real options approach to investment opportunity
S	Stock price	Present value of the expected cash inflows from project
X	Exercise price	Present value of the expected expenditures needed to accomplish project
σ	Volatility	Uncertainty of the expected cash flows from the project
r	Risk-free rate	Time value of money
t	Time to expiry	Period over which the investment opportunity is available
δ	Dividends	Cost to preserve option or explicit cash payout by the project

Source: Remer et al., 2001, pg 99.

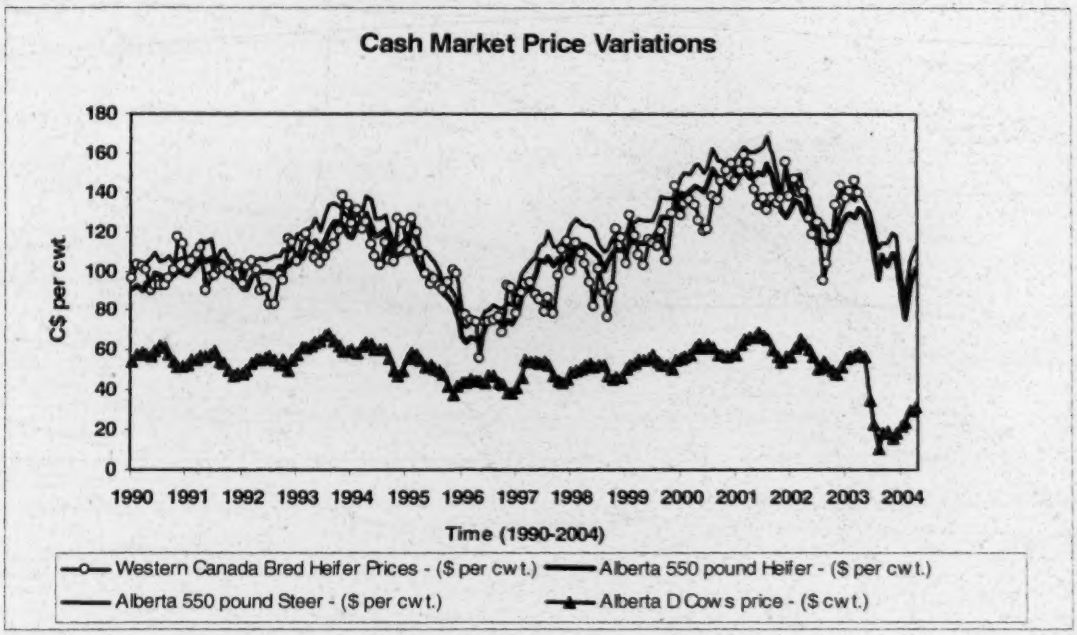
Table 2.2 Ten Most Important Risk Sources

Risk Sources Affecting Income	Average Rating	Rank of Importance
Commodity price variability	**4.5**	**1**
Commodity yield variability	**4.3**	**2**
Change in input costs	4.3	3
Changes in environment regulations	4.3	4
Unforeseen litigation	3.9	5
Changes in machinery costs	3.9	6
Injury, illness or death of operators	3.8	7
Changes in interest rate	3.8	8
Availability of skilled labor	3.7	9
Family health problem	3.7	10

Source: Texas and Kansas Risk Management Education Teams, 1998.

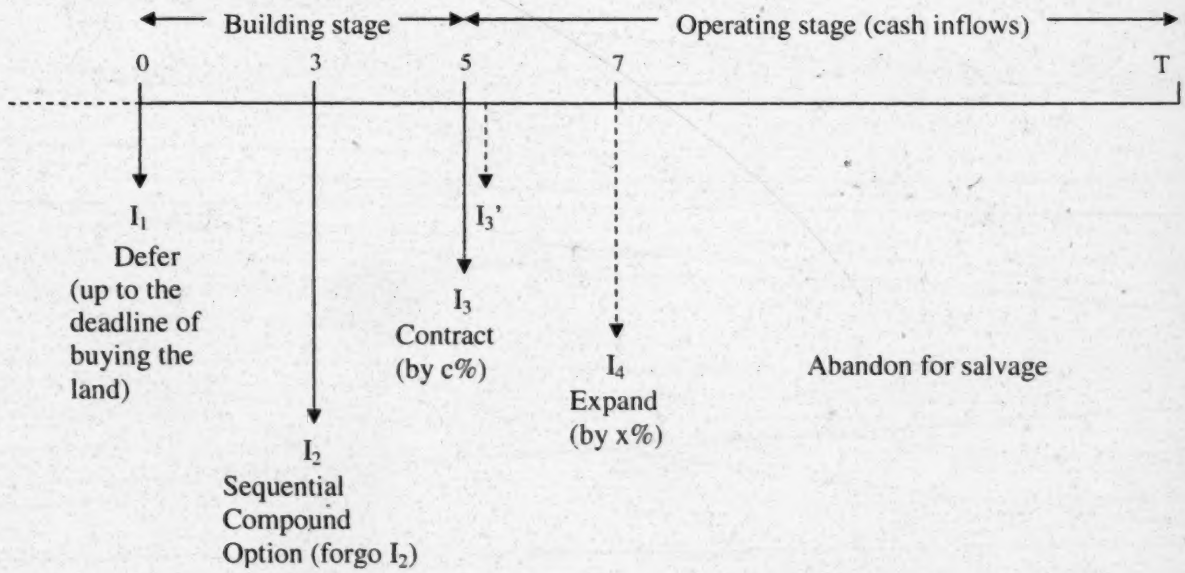
2.6 Figures for Chapter 2

Figure 2.1 Cash Market Prices of Calves and Cows (1990-2004)



Source: Data complied from AGDATA, AAFRD.

Figure 2.2 A multistage project requiring a series of outlays (vertical arrows, I_S), allowing management the flexibility (collection of real options) to defer, abandon, contract, or expand the investment



Source: Trigeorgis, 1993, pg. 3.

Figure 2.3 Multiplicative Binomial Model after Two Periods

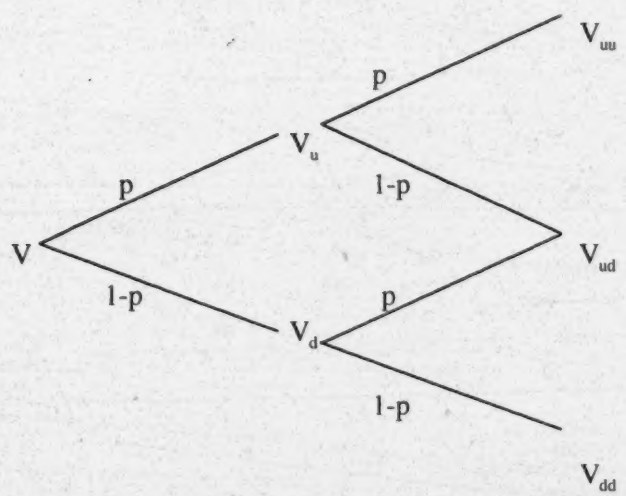


Figure 2.4 The Structure of Three-dimensional Binomial Pyramids

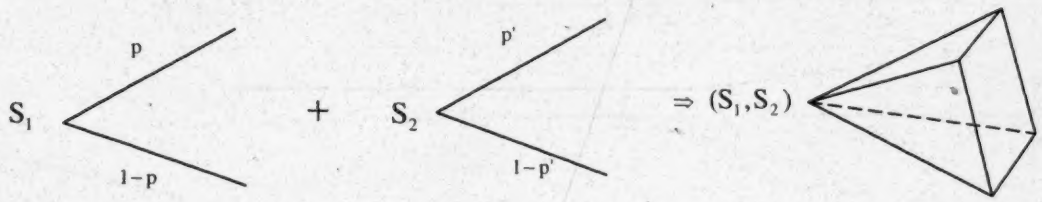
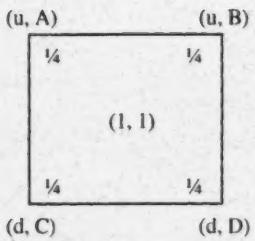
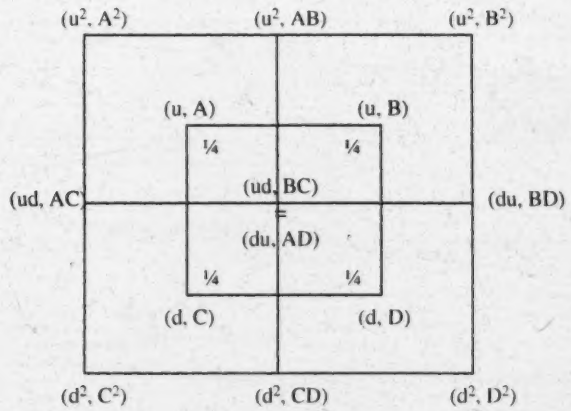


Figure 2.5 The Three-dimensional Binomial Pyramids with One and Two time Steps



Move 1



Move 2

Source: Rubinstein, 1995.

Chapter 3: Investment Decisions in the Cattle Industry and a Real Options Analysis

This chapter starts with an overview of Alberta's cattle industry. Before determining the types of real options in each sector of the Alberta cattle industry, the major investment decisions within each sector are identified in the chapter. Next, the different types of real options embedded in the investment decisions are classified and explained. After the real options are framed, major sources of risk are assessed in the payoff functions. Finally, the chapter discusses the real option valuation methods for the underlying real options in different sectors.

3.1 Overview of Alberta Cattle Industry

Alberta's cattle industry has experienced steady growth since 1986, reaching a peak of almost 2.1 million beef *cows*[18] and replacement *heifer* inventories in 1995, before falling off slightly (Alberta Agriculture, Food and Rural Development, 2001) as shown in Figure 3.1. The province is holding steady at about 40 percent of the total Canadian beef cow herd since 1995 (Figure 3.2). Much of this growth paralleled the growth in feeding operations in Alberta. Indicated by the Canfax "Cattle on Feed" report, as of Jan. 2005, 61% of the province's feed yards fall into the 1,000 to 5,000 head capacity range and hold 20% of Alberta's feeding capacity. The large size operation group (20,000+ head standing capacity), comprising 5% of the total number of feedlot operations, holds 37% of total feeding capacity. As shown in Figure 3.3, in year 2004, approximately 2.2 million *fed cattle* were produced in the province of Alberta. Alberta has increased its share of national fed cattle federally inspected (FI) slaughter from 47 per cent in 1984 to 66 per cent in 2004 (Figure 3.4).

Cattle production in Alberta can be broadly described in three separate sectors: cow/calf, backgrounding, and feedlot. Cow/calf and finishing are comprised of operations ranging in size and specialization while backgrounding is an industry link between the cow/calf sector (producing weaned calves) and the feedlot sector (producing fed cattle). This structure of Alberta cattle industry is further complicated

[18] For terminologies and definitions in the cattle industry, please see Table 3.1.

by the various production alternatives at calf weaning and the *retained ownership* of calves.

The weight of calves born in spring on specialized cow/calf operations at weaning can range from about 160 kg (350 lbs) to 295 kg (650 lbs) in late fall, depending on calving period, genetic background of the calf and pasture conditions during the grazing season. The heavier calves are fed a *high energy finishing ration* in fall and are to be finished in the following spring. The lighter weaned calves are either backgrounded on a *low energy feed ration* for the winter or retained on a *drylot* program before they are placed back on grass or on a feedlot finishing program. These possible alternatives are illustrated in Figure 3.5.

Short term market fluctuations have an impact on the decision of when to release the calves to the market. Retained ownership has advantages in increasing marketing flexibility (e.g. not having to sell calves when there is high supply of weaned calves in the fall market) and delaying the transaction cost (e.g. advertising expense, negotiation cost). Maintaining ownership of weaned calves can also allow producers of genetically superior cattle to capitalize on more of their genetic investment (Lipinski, 2001). However, with retained ownership, the cash inflows from selling calves are delayed which may result in short-term cash flow shortage.

Overall, the retained ownership strategy and biological aspects of the production system have complex effects on the short- and long-term marketing decisions of cattle producers. However, for simplicity in this research, it is assumed that calves grown on cow/calf operations are marketed in fall to backgrounding operations after weaning. The backgrounding operations feed the lighter weaned calves to heavier weights before they enter the feedlot for finishing. Each of the three sectors is modeled as an independent enterprise. This simplified process is depicted by bold arrows in Figure 3.5.

3.2 Investment Decisions in Different Sectors of Cattle Production

Identifying the investment decisions in different sectors of cattle production is a process that is contingent on the unique attributes of the local production system. The information employed in the following discussion of the local cattle production

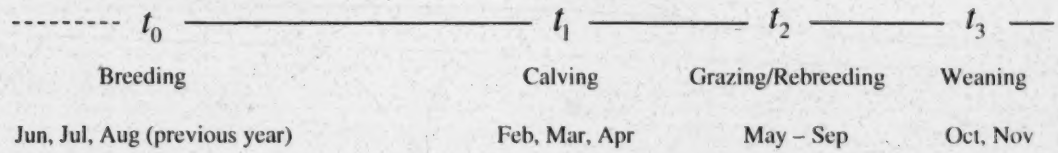
system and the production timelines of the different sectors of Alberta's cattle industry is based on expert opinions from Mr. Dale Kaliel, Sr. Economist in beef production economics and beef specialist Mr. Sandi Jones, Alberta Agriculture, Food and Rural Development (AAFRD). Other information and data sources are: Saskatchewan Agriculture & Food (SAF), Manitoba Agriculture & Food (MAF) and the website of Alberta Beef Producer.

3.2.1 Key Investment Decisions in Cow/Calf Operations

Cow/calf operation is the starting point for commercial beef production. The production in cow/calf operation is normally based on an annual schedule, with cows usually producing one calf per year. Heifers typically produce their first calf at two years of age and have up to eleven reproductive years. A production cycle is described below.

Production Timeline

Traditionally, most cow/calf producers in Alberta breed their animals in June, July or August so that most calves are born nine months later in February, March or April of the following year. Then cows and calves are placed on pasture during spring, summer and fall. In typical operations, calves are weaned from cows in fall, from October to December, when they reach a weight of about 230-250 kg (500-550 lbs). The production timeline in one cycle is illustrated as following:



Previous Research on Investment Decisions in Cow/Calf Operations

The investment decision of the breeding herd replacement in cow/calf operation has been addressed frequently in the agricultural economics literature. Bentley, Waters, and Shumway (1976) studied the optimal replacement age for beef cows under stochastic calving weight and cow life. Trapp (1986) developed investment principles that resulted in the separation of the investment (replacement)

and disinvestment (culling) decision allowing the herd size to fluctuate overtime. Frasier and Pfeiffer (1994) modeled the optimal beef cow replacement intervals by considering the dynamic effect on future productivity when biological response is uncertain. Falconer, Long, and McGrann (1996) developed a discrete-event simulation model in a computerized expert system to aid investment decisions on the beef cow replacement and herd size expansion under uncertainty relating to reproduction and market price. Mathews and Short (2001) and Ibendahl et al., (2004) studied the impacts of variable net replacement/culling rates and the different economic lives of the *open beef cows* on the replacement decision.

The review of the previous research reveals that most of the beef cow replacement theory is based upon the principle of maximizing net present value or specific profit functions. The replacement decisions are often examined in a present value framework which compares the gains from keeping the cow for another time period with the opportunity gains from a bred heifer during the same period. However, in most studies, the assumptions of constant herd size and arbitrarily specified life span of breeding herd in the investment decision modeling are imposed to make the use of traditional NPV model possible. In fact, the cow/calf producer's ability to manipulate herd size may provide a more profitable opportunity under the uncertain environment (Trapp, 1986; Frasier and Pfeiffer, 1994). By expanding or contracting the herd size according to the changing market conditions, long-run cow herd profits can be enhanced and potential cash flow shortage reduced. Thus the investment decisions to expand or contract the breeding herd size, more specifically, the optimal timing of buying and selling females for herd expansion/contraction seems to have a significant effect on herd profitability. In the province of Alberta, the decision to expand/contract the breeding herd size is identified to be one of the important investment decisions faced by individual cow/calf producers (Kaliel, 2005).

The Underlying Investment Decision

This study will focus on investment decisions of expanding or contracting the breeding herd size. There are two likely scenarios for the expansion of beef cow herd in Alberta. A producer can retain heifers from the previous year's calf crop and

breeds them in summer for spring calving in the following year or buy *bred heifers*/cows in fall for calving in the following spring. Retaining heifer means cow/calf producers forgo current sales of calves. The alternative, expanding the herd size through purchasing bred heifers/cows, means the timing between the investment and the birth, production and sale of offspring is a year quicker than retaining heifer calves. Other advantages associated with buying cows may be improved genetics, time and trouble saved of managing and breeding retained heifers. The size of the expansion will not be restricted by the number of heifers available at the ranch. However, the uncertainty of buying the cows is raised by variations in bred heifer/cow price and unknown genetics. In balancing the advantages and disadvantages, expansion through purchasing cows is chosen in this study. Herd contractions are comparatively simple. Breeding cows are sold to other producers or processing plants to generate sales revenue and cost savings.

3.2.2 Key Investment Decisions in Backgrounding Operations

Backgrounding is the process of feeding younger, weaned calves a high forage diet, usually low energy growing rations, either in a drylot or on *pasture* to increase their weight to meet the feedlot demand for calves. The preferred body type for backgrounding calves is a small to medium framed[19] animal. Small to medium frame calves fed *high energy rations* soon after weaning results in early finishing and lighter weights at slaughter. On the other hand, keeping large frame calves on the low energy growing ration for too long can cause very heavy finishing weights which are subject to reduced profits and packer discount (Saskatchewan Agriculture & Food, 1997). Purchase weights of 160 kg (350 lbs) – 250 kg (550 lbs) steer calves are popular for backgrounding. Heifers tend to weigh 14 – 23 kg less than steers at a similar age. Calves are sorted into consistent groups based on size and quality when entering the backgrounding sector. The energy level of the feed should be increased or decreased for the *feeders* in different groups to develop sufficient frame and gain designated weight. By the time the backgrounding process is completed, *feeder cattle* reach the consistent weight of 360 kg (800 lbs) - 410 kg (900 lbs) and then move to the

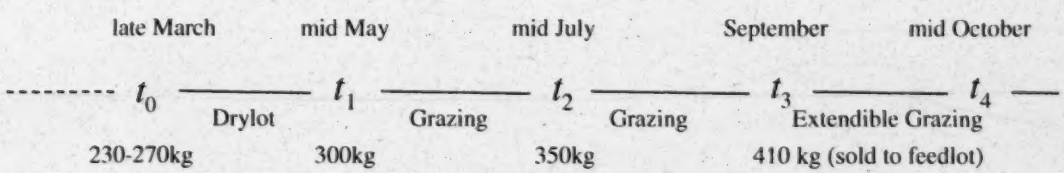
[19] See Table 3.2 for details of specifications for frame sizes.

finishing phase. Feedlots are willing to purchase backgrounded cattle because there is reduced sickness, decreased input time, and consistent weight gains established.

Production Timeline

There are different production systems which may be used to background cattle. Calves born in spring can be bought in fall, fed in a drylot at a lower rate of gain during winter, and sold in four to six months. Rations are based on higher quality forage with very little lower quality feeds such as straw, chaff, or grain screening pellets. This type of production system is called winter backgrounding. Alternatively, calves born later can be bought in spring, grazed on a higher quality forage pasture over the summer. This is called summer backgrounding (AAFRD, 2003).

Based on beef cow specialist opinions, forage quality and quantity are usually high during summer in the province of Alberta. Summer backgrounding is popular and thus is chosen as the production system to evaluate in this study. In summer backgrounding operations in Alberta, calves are often bought in spring and fed in the drylot with a low energy ration for a 60 day period (e.g. late March to mid May), from t_0 to t_1, before moved to pasture. When the summer grazing season in Alberta begins in t_1 (mid May), feeder cattle are placed in a forage pasture. Mid May to mid July (t_1 to t_2) is the period for feeder cattle to develop frame and gain weight from 300 kg to 350 kg. Traditionally, feeders are grazed on pasture to about 410 kg and sold at t_3 (early September) since August and September usually have higher volumes of marketing. The bulk of backgrounded feeder cattle are purchased by feedlot producers at this time. However, under good weather condition and grazing management, feeders can still be left on pasture for a longer period of time until t_4 (mid October).



Previous Research on Investment Decisions in Backgrounding Operations

A study done by Saskatchewan Agriculture & Food (1997) indicates that the profit a producer makes from backgrounding is based on the price spread between the purchasing price of weaned calves and the selling price of backgrounded feeder cattle. The variability of the spread between cattle prices at 230-270 kg (500-600 lbs) and the prices at 360-410 kg (800-900lbs) is the major source of risk to the backgrounding operation (Saskatchewan Agriculture & Food, 1997). Given the production cost, it is very important to make the best choice based on the calculated spread.

Kastens and Schroeder (1994) studied the feeder cattle placement decisions and suggested that at any point of the production timeline beyond t_1, backgrounding producers can choose either to place cattle in finishing feedlots, or to leave them in backgrounding phases for growing. "This flexibility, although biologically constrained to some extent, is caused by the existence of a range of weights over which feeder cattle can be (and typically are) placed in a finishing feedlot" (Kastens and Schroeder, 1994 pp. 339). In Mathews and Short (200!)'s study, they suggested that an integrated cow/calf operator was able to choose between keeping and selling some or all individual heavy calves in each calf crop according to projected market conditions. In practice, the keep-or-sell decision provides a viable alternative for backgrounding producers since other cattle feeders and *short keep producers* are willing to buy backgrounded cattle at lower weights to maximize the use of their facilities and feed.

The Underlying Investment Decision

This study evaluates the keep-or-sell decision faced by the backgrounding producers. More specifically, after the feeder cattle are placed on a pasture to gain weight, backgrounding producers can decide whether they should keep the group of feeder cattle until the end of the grazing season or sell the cattle at a certain point during the grazing season. This decision is determined by comparing the expected present value of backgrounding feeder cattle until they reach feedlot demand weight with the net return of selling the cattle at prevailing prices for lighter weights during

the grazing season. The expected present value of the feeder cattle is mainly driven by the spread between 500-600lbs calf price and 800-900lbs feeder cattle price. If the spread is large, the expected present value is high, which suggests that keeping the feeder cattle and feeding them to designated weights may be in backgrounding producers' best interests. However, when the expected present value of the feeder cattle remains low due to the persistently low spread, producers can sell the feeder cattle at lighter weights so as to mitigate loss.

3.2.3 Key Investment Decisions in Feedlot Operations

Historically, cattle were finished in small farm feedlots. Today, highly specialized cattle feedlots feed most of the province's cattle to slaughter weight. Feedlot owners either purchase heavier calves or feeder cattle from cow/calf or backgrounding operations, or they *custom feed* cattle for clients on a fee-for-service basis. These cattle with large body frames but little fat will be kept in the feedlot and fed a high energy finishing ration until they achieve the desired level of finish.

Production Timeline

Weight of cattle entering the finishing program dictates the feed ration used and the time on feed. Cattle that are heavier when they enter the feedlot from the backgrounding stage, for example, steers that weigh 400 kg, are fed high energy rations within two weeks of entering the feedlot. On the high energy rations, most cattle gain about 1.3 kg (2.8 lbs) or more per day. High energy finishing rations are normally fed to cattle for at least 100 days depending on the initial weight when entering the feedlot. The general rule in the industry is that steers are normally processed at 520 kg (1,150 lbs) – 590 kg (1,300 lbs), and heifers at 475 kg (1,050 lbs) – 520 kg (1,150 lbs). Generally, the feedlots in Alberta have a *turnover rate* of two times per year. The turnover rate requires continuous supply of feeder cattle instead of seasonal supply. It is assumed feeder cattle availability is not a limiting factor in this study.

Previous Research on Investment Decisions in Feedlot Operations

According to Viney's study (1995), feedlot producers can target a return from a *pen* of feeder cattle before purchasing the feeder cattle from the backgrounding sector to allow for higher returns and lower volatility. Traditionally, the expected basis of the live cattle futures prices could be used by individuals targeting cattle feeding returns. If the expected return is below the targeted return, feeder cattle will not be purchased to place on feed.

Kastens and Schroeder (1994) concluded that earning a positive recent profit (e.g. the profit from finishing the cattle in the previous turnover) might be a more important determinant of current feeder cattle placement decision than the futures prices. The implication of this result is that cattle feeders use recent actual profit as a significant information source for making decisions about whether to place a pen of feeder cattle in feedlot now or later. May and Lawrence (2002) further suggested that the decision to place feeder cattle on feed could be made during the entire feeding period instead of at the beginning of the feeding period. This wider decision window allows producers to postpone the placement decision and wait for a more favorable pricing opportunity to bring in the feeder cattle during the feeding period. Therefore, the timing of feeder cattle placement becomes an important issue in the decision making process for cattle feeders.

The Underlying Investment Decision

The underlying investment decision in the feedlot operation is the decision when to acquire and place feeder cattle in a feedlot. The profit a finishing feedlot producer who purchases feeder cattle from the backgrounding sector makes for the feedlot operation is based on the price spread and the weight gained by the animal. The decision criterion is the recent profit of finishing cattle in the feedlot. At the beginning of the feeding period, if the expected profit is high, feedlot producers place more feeder cattle in feedlots. Less feeder cattle are placed in feedlots given zero or negative recent profit.

The time frame for this decision making is usually one turnover in the finishing feedlot. Together with the keep-or-sell decision in the backgrounding sector,

these are considered the short-term investment decisions in the cattle production in contrast to the long-term herd expansion/contraction decision in the cow/calf sector.

3.3 Real Options Associated with the Key Investment Decisions

After identifying the types of investment decisions for the three sectors respectively, the real options associated with these different decisions are discussed next. Once the classification of the real options is completed, numerical options algorithms can be applied to price the underlying real options in the different sectors of the Alberta cattle industry.

3.3.1 Real Options in Cow/Calf Operations

The underlying investment decision within the cow/calf sector is the decision to expand or contract the breeding herd size. This decision is complicated by the market risk and production risk associated with the cow/calf operation, such as nonconstant prices of calves and bred animals, and the expected productivity of cows over their life spans. In the real options literature, the real options embedded in this type of decision are the option to expand and the option to contract. The option to expand is made by an investment outlay on some additional bred heifers, while the option to contract is made by selling part of the breeding stock.

In the option to expand, the payoff from a unit expansion of the cow herd is measured by the difference between the cost of obtaining an additional cow and the sum of discounted future annual net incomes defined as the economic value[20] of this additional cow. Thus, a unit expansion in the cow/calf operation can be considered as an operation that converts an extra input (a beef cow) to some future output mix (mainly calves) at a conversion/production cost. With an opportunity to expand in the future, both the cost of bred heifer and the expected economic value are stochastic variables. Intuitively, this payoff pattern is analogous to a spread option described by Shimko (1994). More specifically, it is defined as a processing spread which is the spread between the input assets to a process and output assets from the same

[20] Hughes (1999) defined the economic value of a cow as the sum of that cow's future annual net cash incomes plus her final cull market value discounted back to the purchase date's dollar.

production process. Therefore, in the cow herd expansion, the input is the cost of acquiring a cow while the output is the economic value of the cow.

Spread Options

Because most applications of the spread option discussed in Section 2.3.3 have been found in the financial derivatives market, the time horizon has generally been short. In the real options analysis, however, the underlying assets are different from the commodity futures of the outputs from instantaneous production processes. Specially looking at bred heifers/cows as potentially productive capital assets over several production periods, the separation of the capital investments to acquire the bred heifers/cows and the economic value of the animals in all the subsequent years fits into the framework of spread option whose payoff depends on two uncertain assets.

In making an investment decision to expand/contract the breeding herd size, the timing of adding/selling beef cow is critical to long-run profits because of the beef price variation (Hughes, 1999). When producers decide to expand the herd size immediately without waiting, the price of the bred heifers/cows can be observed from the current market with little uncertainty. However, the economic value of the cows in the subsequent years is uncertain because of production risks and uncertain future calf prices. Therefore, by choosing to expand now, the spread which is the difference between the economic value of the purchased cows and the cost of acquiring the cows is subject to uncertainty. The cow/calf producer may be hesitant to expand now even though the expected return of doing so is positive under the traditional static NPV rules. The reason for the hesitation may be that the producer incurs a partially irreversible cost in time and money to buy additional cows (buying commission, transportation, and value of cows) and starts feeding them under uncertainty over returns. In addition, current additions to the herd are competing with future additions for the fixed resources of the cow/calf enterprise (Trapp, 1986).

Following Dixit and Pindyck, when an irreversible investment decision is postponable and waiting may improve the estimates of profitability, a real option value arises to waiting. With an immediate purchase now, the producer forgoes this

value of waiting (value of option to defer). As an alternative to making the decision to "expand" or "do not expand" now, a producer can wait and then decide in a later period to invest when the uncertainty associated with the economic value and the spread is resolved to some extent. Therefore, the option to defer which is valuable to the producer is analogous to a spread call option.

Let S_1 represent the total discounted future net income (the economic value) of a cow during its life span in $ per head, S_2 the investment to acquire a beef cow in $ per head. If the cow/calf operation is already producing at full capacity, additional land rent, X, for the expansion should be included as a fixed cost. Therefore, the cow/calf producers have the right to expand the operation by purchasing Q units of beef cow and generating future annual incomes from sales of calves and cull cows. Assuming the cow/calf enterprise operates in discrete time, then the maximum revenue R from the expansion in following periods is given by:

$$R = \max\left(\sum_{i=1}^{Q} S_{1,i} - \sum_{i=1}^{Q} S_{2,i} - X, 0\right) \tag{3.1}$$

where i denotes the i th cow in the herd expansion, and X is the additional land rent if necessary. The payoff resembles a spread call option because the cow/calf producer has the right, but not the obligation, to buy additional beef cows during the period over which the investment opportunity is available.

The maturity of the call option can be extended to the succeeding years. And the herd expansion can take place in any of the operating years. So the spread call option has an American exercise feature during its life. Since bred heifers are often bought during late fall for spring calving in the province of Alberta, the call option is most likely to be exercised at some specific time points (e.g. every October to December) prior to the maturity. From Section 2.2.1, this form of exercise pattern is known as Bermudan exercise. Therefore, the spread put option has both American and Bermudan exercise features. The decision to expand now is only made when the expected spread is high enough to compensate the forgone value of waiting.

The decision to contract the herd size can be modeled into an American or Bermudan spread put option. The payoff is

$$R = \max\left(\sum_{i=1}^{Q} S'_{2,i} + X - \sum_{i=1}^{Q} S'_{1,i}, 0\right) \quad (3.2)$$

where X denotes the cost savings in pasture renting and other relevant costs, S'_2 is the sales revenue from selling the cows, S'_1 is the forgone economic value from keeping the breeding cows.

Sources of Risk

Cow/calf operations are exposed to a variety of risks, such as those defined in Section 2.2.3. As for the breeding herd expansion/contraction, the capital investment in acquiring the extra bred heifers or the sales revenue from selling the breeding cows, are subject to the bred heifer price/cow price risk.

Determining the risk components in the expected/forgone economic value of cows in herd expansion/contraction is more complicated. According to Trapp (1986), the motivation for breeding herd expansion and contraction emerges from the changing market conditions, especially the risk associated with the price of the calf. The variations in cull cow price, production costs and hay price also add to the degree of risk of the expected/forgone economic value of cows. Furthermore, the review of previous research (Trapp, 1986; Frasier and Pfeiffer, 1994; Ibendahl et al. 2004) indicates that production risks arising from cow mortality, culling rate of the mature cows, weaning rate of the calves and variations in calf weights have significant impacts on income.

The expected productivity of the cow changes over her life span while the prices received for the calves produced and the cull cows fluctuate over time. As a result, the cash inflows change from year to year. Meanwhile, the cost of producing a calf also changes with cow age in terms of feed intakes and with the year-to-year variation in feed price. These risk factors jointly affect the economic value of the cows in the breeding herd expansion/contraction. According to Copeland and Antikarov (2001), the multiple sources of risk associated with the project can be combined into a spreadsheet, and produce an estimate of the economic value conditional on the set of random variables drawn from each individual source. The

method to incorporate the multiple sources of risk associated with the economic value of cows into the spread option valuation model will be discussed in Chapter 5.

3.3.2 Real Options in Backgrounding Operations

The keep-or-sell decision in the backgrounding enterprises presents some cattle marketing flexibilities desired by the backgrounding producers. The backgrounding producers may be better off with a flexible cattle marketing method over a rigid alternative that confers no choice or less choice. As mentioned in Section 3.2.2, if the expected present value of the feeder cattle at feedlot desired weight turns out to be lower than expected, a backgrounder has the right to sell the lighter feeder cattle to short keep producers at strike prices over the grazing season to mitigate loss. Therefore, the keep-or-sell decision in backgrounding is analogous to a put option.

Put Option

Generally, backgrounding producers purchase and keep all the feeder cattle before the grazing season begins in the cattle industry. The keep-or-sell decision is usually made after the initial drylot period which takes place from late March to mid May. When the grazing season starts in May, the backgrounding producer holds the put option which expires prior to the end of the grazing season and enables selling the feeder cattle before they reach standard feedlot demand weight.

Setting up a strike price for the put option is crucial. The strike price of the put option inherent in the keep-or-sell decision is the revenue from selling lighter feeder cattle. During the period in the backgrounding sector, the animal weight gained, w_t is a function of time on pasture based on the growing curve of cattle. The feeder cattle can gain more than 150 kg over the life of the put option associated with the keep-or-sell decision. So the strike prices which are net returns from selling feeder cattle $I_B(w_t)$, received from exercising the put option at different phases during the grazing season change in concert with feeder weights. This requires a modification to the put option to let strike price change over time. Mun (2002) addressed this issue

via an option with changing strikes. Based on the time-step size, the different strike prices associated with different time periods can be mapped into the binomial lattice.

Sources of Risk

A general risk inherent in buying and selling feeder cattle in a competitive market is price risk (Fausti and Feuz, 1995). In a backgrounding operation, the cost of weaned calves is known at the time they were bought and deemed partially irreversible. The expected present value of backgrounding a group of feeder cattle $\tilde{V}_B$ is a stochastic process driven by the variation of the difference between the cost of weaned calves and the sales revenue of feeder cattle at feedlot demand weight.

The strike prices of the put option are the net returns of selling lighter feeder cattle $I_B(w_t)$, which are determined by feeder cattle prices at lighter weights such as feeder cattle prices for five to six; six to seven and seven to eight hundred pound animal. The cash market prices of feeder cattle at lighter weights exhibit variability from year to year as a result of supply and demand relationships. Therefore, the payoff of the put option at the exercise date of the option is given by:

$$\max(\tilde{\tilde{I}}_B(w_t) - \tilde{V}_B, 0) \qquad (3.3)$$

where $\tilde{V}_B$ is the stochastic present value of the net return from backgrounding a group of feeder cattle, the strike price $\tilde{\tilde{I}}_B(w_t)$ is the stochastic revenue from selling the feeder cattle at lighter weights driven by multiple stochastic processes, representing feeder cattle prices at different cattle weights. It is concluded that the payoff function of the put option in the backgrounding operation is associated with multiple sources of risk.

3.3.3 Real Options in Feedlot Operations

Under a real options framework, the decision to purchase feeder cattle at placement time is a "place an additional pen on feed now" or "place this additional pen later" type of decision. Suppose the purchase decision is made now, a partially irreversible investment immediately takes place which includes the transaction cost of purchasing the feeder cattle and the subsequent cost of feeding under the condition of

uncertain returns[21]. Alternatively, finishing feedlot producer can postpone the purchase of a pen of cattle and wait for better pricing opportunity for selling fed cattle or for purchasing feeder cattle until some later periods. Intuitively, the feedlot producers may hold a valuable real option of waiting regarding the purchase decision of the feeder cattle. The cattle are purchased right away only when the expected return is high enough to compensate this forgone option value of waiting.

The payoff of the decision to feed a pen is based on the spread between the cost of acquiring feeder cattle and the revenue from selling the fed cattle less the high energy feed ration cost and the yardage cost. The option to wait can be transformed into a spread call option mechanism.

Spread Call Option

The spread is the difference between the return from selling the fed cattle and the cost of purchasing the feeder cattle less the feed cost[22] and the fixed yardage cost. Both fed cattle price and feeder cattle price are subject to uncertainty. Let $\tilde{P}_{fed}$ represent the expected price of fed cattle in $ per hundred-weight, Q_{fed} the total output weight of a pen of cattle in hundred pound, $\tilde{P}_{feeder}$ the expected price of feeder cattle in $ per hundred-weight, Q_{feeder} the total input weight of a pen of feeder cattle in hundred pound, and X_F the total yardage cost and feed cost. The spread of a pen of cattle in the feedlot operation is given by

$$R_F = \left(Q_{fed}\tilde{P}_{fed} - Q_{feeder}\tilde{P}_{feeder} - X_F\right) \tag{3.4}$$

Therefore, the payoff of the option to wait (spread call option) is:

$$\max\left(Q_{fed}\tilde{P}_{fed} - Q_{feeder}\tilde{P}_{feeder} - X_F, 0\right) \tag{3.5}$$

where "~" denotes a stochastic price process.

Sources of Risk

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[21] Although the uncertainty can be reduced using live cattle futures, it is still subject to basis risk and currency risk. The live cattle basis is the difference between the Chicago Mercantile Exchange futures market price and the Alberta cash price adjusted to the same currency on a specific day at a specific location.

[22] Barley represents a major feed used in Alberta. Short term barley hedges are used by cattle feeders and cattle owners to lock in production costs within a feeding period.

Traditionally, cattle futures can be used to establish a price on feeder cattle several months in advance (Thompson and O'Mary, 1984). However, in making current feeder cattle placement decision, cattle feeder uses recent actual profit determined by cash market price rather than futures price as the determinant (Kastens and Schroeder, 1994). Therefore, this study will focus on the cash market price of fed and feeder cattle. Fed and feeder cattle prices are the primary sources of market price risk for cattle feeders. Research suggests that as much as to 80% of the variability in cattle feeding profits is explained by the variability in fed and feeder cattle prices (Mark et al. 2000; Lawrence et al. 1999; Schroeder et al. 1993) since the profit a feedlot makes is based on the spread between feeder cattle price and fed cattle price. Therefore, the sources of risk associated with the option to wait in the feedlot sector chiefly consist of the fed cattle price risk and the feeder cattle price risk which can be measured by their historical price volatilities.

3.4 Real Options Algorithms

After the real options and sources of risk in the three sectors are identified, the option pricing models outlined in Chapter 2 can be applied to the valuation of real options. Given that analytical solutions for real options may not be available in most complex real-life option situations (Schwartz and Trigeorgis, 2001) this research focuses on numerical option valuation techniques.

According to the payoffs, the real options in both cow/calf and feedlot operations can be evaluated using the spread option algorithm because the payoff functions contain two risky assets. This study employs a spread option approximation in a three-dimensional binomial model developed by Haug (1998) using Rubinstein's algorithm. Before applying Haug's three-dimensional binomial model to calculate the spread options in the cow/calf sector and the feedlot sector, several input variables have to be specified. For example, the value of the spread call option in the herd expansion decision depends on several basic variables presented in Table 3.3. The effects of various risks associated with the two assets are measured by the volatilities of the returns of the real assets whereas the co-movement of the two real assets is captured by the correlation of returns. These variables are estimated as model

parameters for the spread option model. The procedures of estimating the parameters for the spread option valuation models are discussed in Chapters 4 and 5.

The put option in the backgrounding sector involves multiple risky assets and thus can not be valued by the multiplicative binomial model or the three-dimensional binomial model. Based upon the review of the option valuation methods in Chapter 2, the Monte Carlo simulation method may provide solutions to the put option inherent in the backgrounding operations. However, setting up the MCS option pricing algorithm is beyond the scope of this thesis. Therefore, the put option in the backgrounding sector will not be numerically evaluated. Nevertheless, the concept of viewing keep-or-sell flexibility in the backgrounding operation as a put option leaves room for future studies.

3.5 Chapter Summary

The real option analysis is particularly useful when an investment decision is irreversible and postponable, and waiting will improve the estimates of profitability under uncertainty. This chapter identifies the opportunities of using real options analysis in the specific investment decisions within each sector of the cattle industry, including the decision to manipulate herd size in the cow/calf sector, the keep-or-sell decision in the backgrounding sector, and the feeder cattle placement decision in the feedlot sector. Next, different types of real options are framed into these decisions to come up with payoff functions with real assets. The sources of risk associated with these asset values are assessed respectively. Finally, the three-dimensional binomial model which is capable of pricing most of options that depend on two risky assets is employed as the major option algorithm for pricing the identified real options in the cow-calf and the feedlot sectors.

3.6 Tables for Chapter 3

Table 3.1 Terminologies and Definitions in the Cattle Industry

Terminology	Definition
Heifer	A young female bovine cow, especially one that has not yet given birth to a calf
Bred heifer	A pregnant heifer that is going to give birth to her first calf
Steer	A young bovine male castrated before sexual maturity and raised for beef
Cow	A mature female bovine
Open cow	An open cow is one that has been found not to be pregnant
Feeder cattle (Feeders)	Cattle ready to be finished for market, weighing 550-650 pounds or heavier
Fed cattle	Steers and heifers that have been fed finishing ration usually for 90-120 days in a feedlot and are ready for slaughter
Ration	Feed or mixture of feed to supply the required nutrients for animal growth
Low energy (growing) feed ration	Ration designed for calves going back on grass or to grow animals before being placed on finishing ration with high fiber, low protein content
High energy (finishing) feed ration	Rations designed to obtain high rates of gain, high in grain content and digestible energy, low in fiber
Pasture	Land or a plot of land used to graze animals
Drylot	An operation or facility, other than a pasture, where animals are fed, confined, maintained or stabled for a period of time
Turnover rate	The number of fed cattle marketed relative to feedlot capacity
Pen	Fenced area based upon a space allowance per animal with a continuous feed bunk on the side of the feed alley
Retained ownership	Cow-calf producers retain the title of the calves after weaning as they move into background and/or feedlot programs instead of selling the calves
Custom feeding	Refers to sending cattle to commercial feedlot that specializes in feeding and managing cattle until they are ready for slaughter
Short keep producer	Producer who purchases cattle at a backgrounded weight and place them on feed for a shorter period of time

Source: *Economic Feasibility of Retained Ownership for Cow/Calf Producers*, 1999; *Backgrounding Beef Cattle in Saskatchewan*, 1997; *The Feedlot*, 1983.

Table 3.2 Specifications for Each Frame Size of Feeder Calf

Large Frame (L)	Feeder cattle in this grade have large frames and are tall and long-bodied for their age. Steers would be expected to produce carcasses with .5 inch external fat opposite the twelfth rib when their live weight exceeds 1,200 pounds. Heifers would be expected to produce choice (equivalent to Canada AAA) carcasses when their live weight exceeds 1,000 pounds.
Medium Frame (M)	Feeder cattle in this grade are thrifty, have slightly large frames, and are moderate in height and body length for their age. Steers would be expected to produce carcasses with about .5 inch fat at twelfth rib at live weights of 1,000 to 1,200 pounds. Heifers would be expected to produce choice (equivalent to Canada AAA) carcasses at 850 to 1,000 pounds.
Small Frame (S)	Feeder cattle included in this grade are thrifty, have smaller frames and are shorter in height and body length than medium frame feeder cattle. Steers would be expected to produce carcasses with about .5 inch fat at live weights of less than 1,000 pounds. Heifers would be expected to produce choice (equivalent to Canada AAA) carcasses at live weights of about 850 pounds.

Source: McKissick, J.C., and D.T. Brown. "Profitable Cattle Marketing for the Cow/Calf Producer." Cooperative Extension Service, College of Agricultural and Environmental Sciences, University of Georgia, 2001. http://pubs.caes.uga.edu/caespubs/pubcd/b1078-w.html

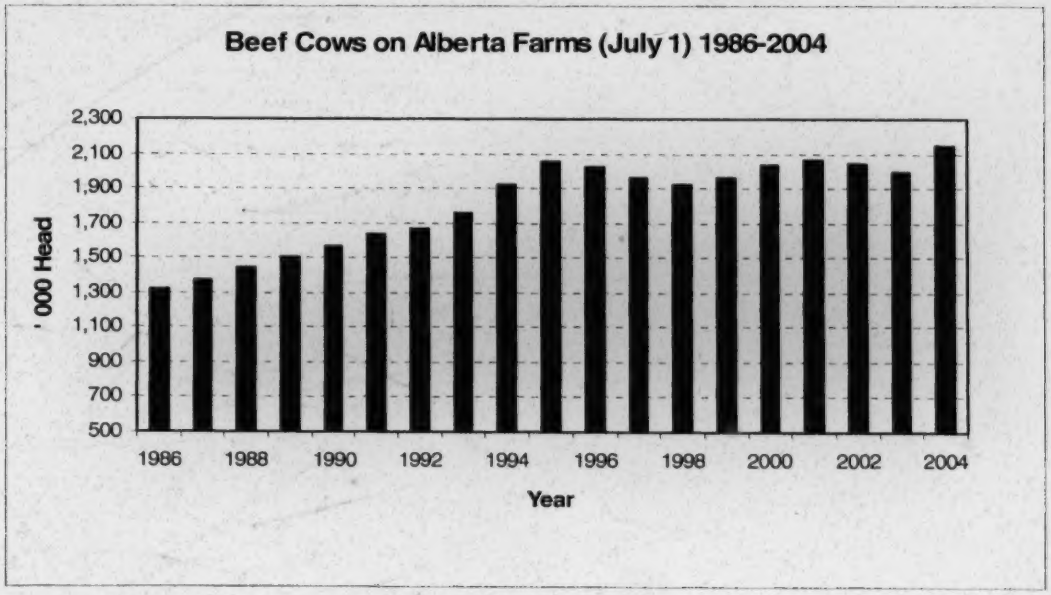
Table 3.3 Basic Variables Employed for Spread Option Valuation in the Cow/Calf Operation

Variable	Variable Description	
	Financial spread option	**Real options in herd expansion**
S_1 *	Asset 1 price	Expected Economic values of additional cows
S_2	Asset 2 price	Cost of acquiring bred heifers
X	Fixed conversion cost	Additional pasture land rent for purchased cows
σ_1 *	Volatility of asset 1 price	Volatility of the returns of economic value of additional cows
σ_2 *	Volatility of asset 2 price	Volatility of the returns of cost of acquiring bred heifers
ρ *	Correlation of two assets	Correlation of the returns from two assets
r_f	Risk-free rate	Time value of money
t	Time to expiry	Period over which the investment opportunity is available
δ *	Dividends	Explicit cash payout by the assets

"*" stands for variables to be estimated, other variable values can be directly obtained.

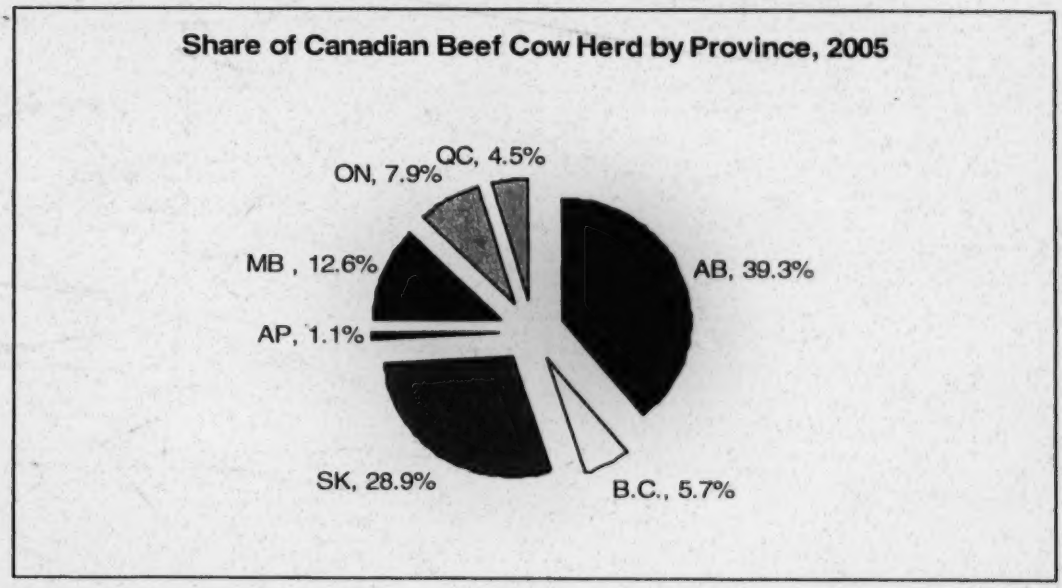
3.7 Figures for Chapter 3

Figure 3.1 Beef Cows on Alberta Farms, July 1, 1986-2004



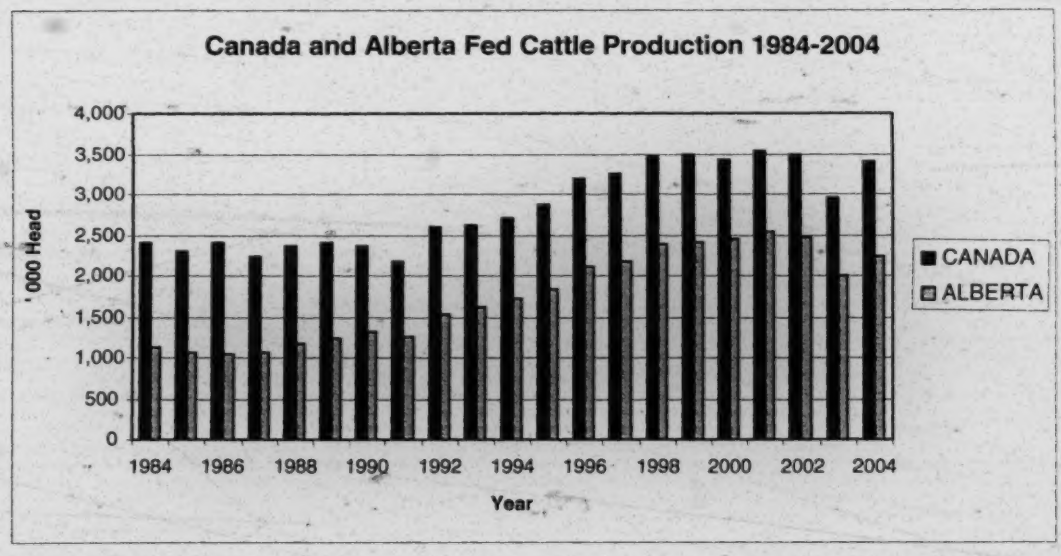
Source: Agriculture Division, Statistics Canada, 2005.

Figure 3.2 Share of Canadian Beef Cow Herd by Province, Jan 1, 2005.



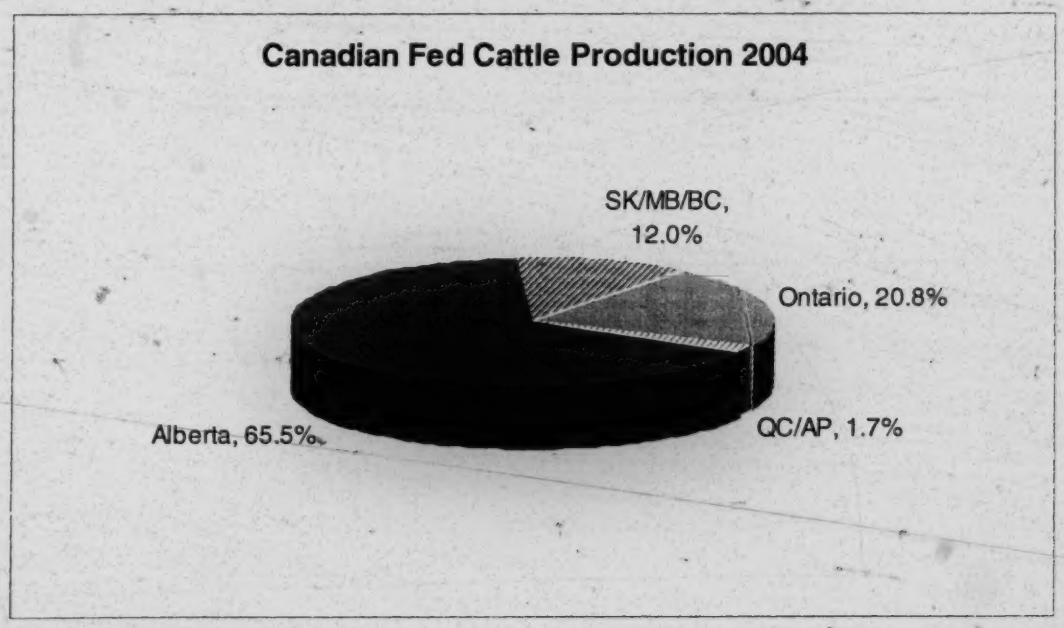
Source: CanFax Annual Report, 2004.

Figure 3.3 Canada and Alberta Fed Cattle Production 1984-2004



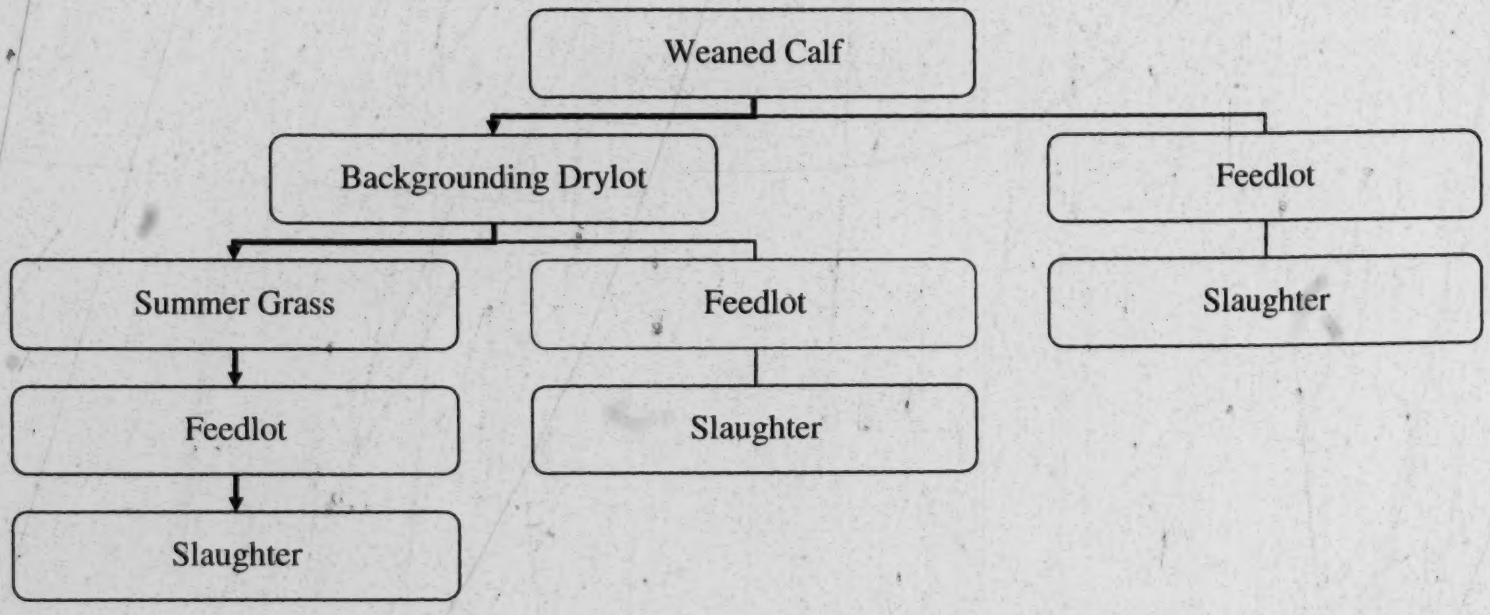
Source: Canfax Report, 2004.

Figure 3.4 Share of Canadian Fed Cattle Production by Province 2004



Source: Canfax Report, 2004.

Figure 3.5 A Schematic of Beef Cattle Production Alternatives in the Province of Alberta



Chapter 4: Methodology and Data

The required data and model parameters for the real option valuation models in the cow/calf and feedlot operations are outlined in Table 4.1. The economic values of cows in the cow/calf operation and production costs in the feedlot operation are identified as secondary data that require additional modeling to determine their values. This chapter first discusses the additional methodology employed to generate secondary data for the real option valuation models. Then a detailed description is provided for data directly available from sources. Finally, data, including the real option model parameters that are not directly available from sources, are identified.

4.1 Additional Methodology and Assumptions to Determine the Economic Value of Cows in Cow/Calf Herd Expansion and Contraction

As illustrated in Table 3.3, the economic value of cows in herd expansion/contraction is a key model parameter for the spread option model in the cow/calf operation. Following Hughes (1999), the expected economic value/forgone economic value of a cow for herd expansion/contraction is determined by summing the discounted annual net cash incomes generated by the cow throughout the production years and her final cull market value. Since cow/calf production is based on an annual schedule, with cows usually producing one calf per year, the market values and annual net incomes are observed and used as discrete annual levels rather than continuous functions of time in the net present value formula.

Let t-12 be the date (month & year) the bred heifer was purchased for herd expansion or the breeding cow was sold for herd contraction where t denotes the year. When the bred heifers entered the cow herd, all heifers were approaching two years of age and were due to calve. Let a be the age of cow in years starting from $a = 2, \ldots, 12$ which implies eleven calving years (production years) maximum in a herd. Sale of offspring is a year after the purchase date of bred heifers.

Assuming there is no production risk and each cow can live to age a, all cows are culled at the end of the (a-1) th production year. The discrete form of Perrin's (1972) net present value formula is often used as a criterion of the investment decision regarding herd expansion:

$$NPV(0)_{t-12} = \sum_{y=1}^{a-1}(1+r)^{-y} I_{t+y} + (1+r)^{-(a-1)} M(a)_{t+a-1} - M(0)_{t-12} \qquad (4.1)$$

$NPV(0)_{t-12}$ is the net present value of the net cash inflows from a cow that is bought as a bred heifer on the date t-12. y is defined as the calving year of age. I_{t+y} is the net annual cash income from a cow in the y th year after being bought in year t. I_{t+y} is subject to time-dependent fluctuations driven by various historical prices. r is the risk adjusted discount rate; $M(a)_{t+a-1}$ is the cull value of a cow *a* years of age bought in year t as a bred heifer and is subject to the time-dependent fluctuations driven by the historical cull cow prices; $M(0)_{t-12}$ is the purchase price of a bred heifer in t-12.

Equation 4.1 can be used to determine if a bred heifer as a potentially productive asset should be purchased. If the $NPV(0)_{t-12}$ is greater than zero, the heifer should be purchased to expand the herd. The herd size should stay unchanged if the $NPV(0)_{t-12}$ is below zero. This criterion of the investment decision in herd expansion is set as a departure point in this study. The first two terms in Equation 4.1 represent the definition of the economic value of a cow. Without the production risk, all the variations in the economic value of a cow bought on different dates are caused by market risk which can be incorporated by using historical price series.

As for the forgone economic value of a herd contraction, the terms in the equation have slightly different meanings. Herd contraction is made by selling breeding cows between the age of 6 and 10 years. Any chosen (*a*-1) is the number of years remaining that the breeding cow is expected to live in the herd. $M(0)_{t-12}$ is the market price of a breeding cow in year t. If the $NPV(0)_{t-12}$ is below zero, the cows should be sold to contract the herd size. If the $NPV(0)_{t-12}$ is greater than zero, the breeding cow should be kept around because the sales revenue of the breeding cow is not sufficient to cover the forgone economic value.

In real operations, cows can be culled in any year during the chosen (*a*-1) production years. Four terms additively determine the expected annual net cash inflow from a cow in production year y: expected revenue from calf sales, expected

revenue from cull cow sales if the cow is culled (zero if not culled), expected winter feed cost and other production costs. These four terms are explained as follows.

Expected Revenue from Calf Sales

Cow/calf producers usually have only one opportunity during the year to generate the main stream of income from selling calves. Expected revenue from calf sales in production year y is the product of the probability that a cow of age *a* will wean a calf and the average price received per head for steer and heifer calves in year t + y. A 50% steer and 50% heifer annual calf crop is assumed when there are multiple cows in the expansion/contraction. The equation below describes how the revenue from calf sales is calculated for year t + y.

$$R_{calf}(t+y) = \Pr_a(\text{weaning a calf}) \times \text{Calf weight}_a \times \text{Price calf}_{t+y} \qquad (4.2)$$

where the expected weaning rate $\Pr_a$(weaning a calf) and the weaning weight of a calf, Calf weight $_a$, are deterministic functions of cow age; Price calf $_{t+y}$ can be obtained from the historical price series of the averaged 500-600 lbs. steer and heifer prices.

Expected Revenue from Cull Cow Sales

In cow/calf enterprises, cull cows constitute a secondary, but major, component of income. Cull cows are made up of open cows and cows with physical problems. Cows that die during the production year have zero salvage value in this study. The equation below describes how the revenue from cull sales is calculated.

$$R_{cow}(t+y) = \Pr_a(\text{culling cow}) \times \text{Cow weight}_a \times \text{Price culled cow}_{t+y} \qquad (4.3)$$

where the expected culling rate $\Pr_a$(culling cow) and the expected weight of cow, Cow weight$_a$ are deterministic functions of cow age; Price culled cow $_{t+y}$ can be obtained from the historical prices series of the cull cow sold at the end of every production year.

Expected Winter Feed Cost

Feed intake requirements of cows were determined based on animal weight predicted at different ages. The forage dry matter intake on a daily basis is generally

2.5% of a cow's body weight. Because of the unavailability of native pasture in Alberta during the winter and early spring months, a winter feeding program is generally employed. In this study, hay is used as winter feed to constitute 50% of the forage intake and pasture is the remainder. The equation below describes how the expected winter feed cost is calculated.

$$\text{Winter feed}(t+y) = \text{Price hay}_{t+y} \times \text{Hay intake}_a \quad (4.4)$$

where $$\text{Hay intake}_a = \text{Cow weight}_a \times 2.5\% \times 0.5 \times 365 / 1000 / 0.907 \quad (4.5)$$

the Hay intake$_a$ and Cow weight$_a$ are functions of cow age; Equation 4.5 converts the calculated Hay intake$_a$ in kilograms to tons; Price hay$_{t+y}$ can be obtained from the historical hay prices in Canadian Dollars per ton (0.907 metric tonne).

Other Production Costs

The other costs portion reflects annual expenses (operating costs and fixed costs) for maintaining a cow of age *a* excluding the cost of winter feed. Other costs are estimated on a cash basis and represent major costs like pasture (constitutes the remaining 50% of the forage intake of cows), veterinary and medicine, miscellaneous cash costs, capital purchases of equipment, facilities and land (use depreciation cost as a proxy). Non-cash expenses, such as unpaid labor and capital interest[23] are not included in the costs.

The net cash flow expected in year t + y from an *a* year old cow was determined by summing the revenue generated from the sale of calves and cull cows and deducting winter feed and other production costs. The calculated net cash flow was then discounted back to year t dollar.

$$\text{Net Cash Flow}(t+y) = (\text{Revenue}(t+y) - \text{Expenses}(t+y))/(1+r)^y$$

$$= (R_{calf}(t+y) + R_{cow}(t+y) - \text{Winter feed}(t+y) - P_{cost}(t+y))/(1+r)^y \quad (4.6)$$

The calculated net cash flows for (a-1) years were then summed up to get the economic value of the cow for herd expansion/contraction in t-12. That is:

[23] Capital interest measures the opportunity cost of investing capital in the cattle enterprise rather than into an investment of other type.

$$S_{1,t-12} = \text{Total Net Cash Flow}_{t-12} = \sum_{y=1}^{a-1} \text{Net Cash Flow}\,(t+y) \qquad (4.7)$$

where $S_{1,t-12}$ denotes the economic value of a cow bought or sold in t-12 (month and year). The profit/loss of the herd expansion is calculated using the economic value of the cows less the initial cost of the bred heifers. In herd contractions, the profit/loss result is calculated as the sales revenue of cows less the forgone economic value of the cows. Beef cow producers should add bred heifers whenever there is a positive profit in herd expansions and sell breeding cows when the herd contractions result in a positive profit.

4.1.1 Incorporating Production Risk

Various production risks associated with the cow/calf operations are incorporated into the calculation of the economic value of cows. The distributional effects of weaning rate, culling rate, and death rate in the context of cow ages result in year-to-year variations in the physical attributes of the cows for expansion/contraction, such as the number of calves weaned/year, cows died/year, and cows culled/year. These attributes also have impacts on the following years: the number of cows left in the herd affects the number of calves weaned; the number of cows culled or died in the subsequent year. In estimating annual costs and revenue of the cows, it is necessary to establish biological relationships to determine the quantity of inputs utilized and outputs generated for each production year.

Weaning percentage, weaning weight, cow weight, culling rate, and cow death rate vary with cow age. These probabilities are introduced to account for production risks associated with the cows in herd expansion/contraction. Following the work of Falconer et al. (1996), at any specific age, the probability of calf weaning, cow culling, and cow death of any cow is independent of any other cow at the same age. A binomial distribution is used to estimate the physical attributes of the herd. The binomial distribution for a random variable x is given as:

$$f(x;n,\theta) = \binom{n}{x}\theta^{x}(1-\theta)^{n-x}, \qquad (4.8)$$

$$\text{for } x = 0,1,\ldots,n.$$

The number of cows in the herd expansion would be specified as the number of trials, n; θ denotes the weaning rate, culling rate, and death rate in percentage, x the number of calves weaned, cows culled, cows died accordingly. Note that n is subject to year-to-year variations of the number of animals left in the herd. For example, when θ denotes the weaning rate, the binomial distribution is used to obtain the probability of observing x successfully weaned calves in the herd of n cows, with the probability of success on a single weaned calf denoted by θ.

The stochastic numbers of calves produced, cows that die, and cows being culled jointly affect the revenues, costs and expected net cash flows each year. For example, the animal culled or died in the y th production year would not generate any costs or revenues in the subsequent years. Therefore, each individual cow in the herd expansion/contraction would have a different life length and a unique economic value.

4.1.2 Size of the Expansion/Contraction

Information on variation in average herd size in the northern part of the province has not been reported directly in the census of agriculture before 2001. However, the average number of cows on Alberta farms has been on the rise. From the census data of agriculture from 1986 to 2001, the average herd size in the province of Alberta expands at a pace of about 3% per year. The deliberate expansion of herd size should exceed this average growth rate to take advantage of favorable market conditions to enhance long-run cow herd profits. On the other hand, percentage of the expansion/contraction in the cow herd is restricted by a cost-minimizing perspective because unrestricted net additions/reductions to expand/contract herd size will eventually raise average total costs of production per unit and in turn reduce the net cash incomes of all animals in the herd (Trapp, 1986).

In the province of Alberta, 10% to 20% is appropriate as the percentage of herd expansion/contraction for local cow/calf producers to accept (Kaliel, 2005). Given the average number of beef cows wintered in the weaned calf enterprise in Peace Lowland area is commonly between 80 to 120 head, the number of cows in a herd expansion/contraction ranges between 10 to 20 head in this study.

4.1.3 Risk Adjusted Discount Rate

As discussed in Appendix A, the Capital Market Line (CML) is used to calculate the expected return on cow/calf operation. Since cow/calf operation constitutes a large portion of a rancher's portfolio, the CML can be used to determine the appropriate discount rate for the operation. The equation for CML is given by Equation A.3 in Appendix A:

$$\overline{R}_p = R_F + \sigma_p \times \left(\frac{\overline{R}_M - R_F}{\sigma_M} \right)$$

where $\overline{R}_p$ = Expected return on the project; R_F = Risk free rate; σ_p = the standard deviation of the project returns; $\overline{R}_M - R_F$ = Risk Premium which is the difference between the expected market return and the risk free rate; σ_M = the standard deviation of the market returns.

The risk-free rate used in this study is 3.5%[24]. From 1948-2000, the average annual return on the market portfolio was 13.09% for Canada while the standard deviation of Canadian Common Stocks return was 16.48%. The market risk premium during the same period was calculated to be 7.09% (Ross et al., 2002). The nominal historical annual return of the economic value of 100 cows in a 100 head cow/calf operation can be simulated by incorporating historical price series and the expected productivity inputs into Equations 4.6 and 4.7 without discounting the net cash flows. Since the economic value of 100 cows constitutes a large portion of the value of the 100 head cow/calf operation (excluding the land value), the variability in the economic value of cows approximates the changes in the value of the cow/calf operation. Therefore, the standard deviation of the historical annual return of the underlying cow/calf operation value plus the variables outlined above should provide adequate information for estimating the risk adjusted discount rate of the cow/calf operation using the CML.

[24] Please see Section 4.3.1.9 for data source and other details.

4.2 Additional Methodology and Assumptions to Determine the Production Cost in the Feedlot Operation

The decision often faced by the feedlot producers is whether to purchase an additional pen of feeder cattle now or later to fill the feedlot. As discussed in Section 3.4, the option to wait inherent in this decision is modeled by the spread option using a three-dimensional binomial model. The parameters that need to be specified for the spread option model in the feedlot operation are tabulated in Table 4.2.

Given the two risky assets in the payoff function in Section 3.3.3 are driven by the variations in fed cattle price and feeder cattle price, the volatilities of the returns of the two assets can be estimated from time series data of prices, while the correlation between the returns of the two assets can be obtained through standard statistical procedures. However, each feedlot enterprise has a unique operation that incurs non-uniform production costs. Generalization of the feedlot operation is needed to facilitate the estimation of the other model parameters for the spread option valuation in the feedlot operation.

4.2.1 Pen Size and Days on Feed in the Feedlot

In feedlot operations, the number of feeder cattle in a pen varies over individual operation, however, 100 to 200 head is a typical pen size in the industry. In this study, 150 head is chosen as the appropriate size for a pen. It is assumed the average weight of steer and heifer feeder cattle brought into the feedlot is 850 lbs. The average finished weight of fed cattle is 1,250 lbs (1,350 lbs for steers and 1,150 lbs for heifers). Assuming the high energy feed ration in the feedlot can provide an average daily gain (ADG) of 3 lb/day, the pen of feeder cattle thus need a total of 132 days to achieve slaughter weight from the day they enter the feedlot.

4.2.2 Production Cost of Finishing a Pen of Feeder Cattle

Barley grain and barley silage are the primary sources of energy and fiber used in finishing rations in Alberta. Barley is the single largest proportion of production cost which often accounts for over 50% of total production cost per feeder cattle. However, when the cost of feeder cattle is included, the cost of barley grain and barley silage becomes relatively small in comparison to the cost of feeder animal.

Therefore it is assumed the production cost per head which mainly consists of feed cost and yardage cost is used as a fixed unit cost in the spread option model.

4.3 Data Description

This section discusses the data used in the study. Distinction is made between data directly available from sources and data not available from direct or secondary sources. A description of data series directly available from sources is provide, which includes the sources, units and time periods. For data not directly available from sources, the next chapter introduces the historical simulation techniques for generating such data.

4.3.1 Data Directly Available from Sources for the Cow/Calf Operation

Northern Alberta, the Peace Lowland area, was chosen to be the location of the cow/calf operation in this study. The average number of beef cows in the cow/calf operation in Peace Lowland area is about 120 cows, higher than the national average (Kaliel, 2004). Models that assist with investments decisions in changing breeding herd size for cow/calf operations in Northern Alberta have equal applicability to other locations with adequate data.

4.3.1.1 Calf Prices

According to the Regional Beef Cow/Calf Operation Profiles (2004), the average weaned calf weight is 263 kg (581 lbs) from the cow/calf enterprise in Peace Lowland area. So the weaned calf prices used are the monthly 5-6 hundred weight (cwt.) heifer and steer cash market prices[25] for the period of January 1976 to April 2004. The data series are obtained from the Alberta Agriculture and Rural Development database AGDATA with series number #640 and #567 for heifer and steer respectively. The prices are measured in Canadian Dollars per cwt. Each data series contains sub-series for south, central and north Alberta. North Alberta price sub-series are used to reflect the local difference.

[25] The two types of futures contracts traded in the Chicago Mercantile Exchange (CME) are live cattle futures and feeder cattle (700-850 lbs.) futures. There is no futures contract on weaned calves.

4.3.1.2 Cull Cow Prices

Cull cows include the cows that are unable to produce a marketable calf in one or more production years or cows that are physically unsound. The monthly D grades[26] slaughter cow prices are generally used as cull cow prices for the period of January 1976 to April 2004. The AGDATA series number for the monthly D grades slaughter cow prices is #563. The price is in Canadian Dollars per cwt. The data series contains sub-series for D1, D2 price, and D3 price. The D1 grade is given to mature carcasses with excellent muscling and external fat characteristics. The D2 grade is given to mature carcasses that exhibit weaker muscling and have poorer external fat characteristics. The D3 grade is given to mature carcasses that have deficient muscling. Following the expert opinion, a weighted average D grades cow price is generated with 80% weight to D1, D2 price and 20% weight to D3 price. This weighted average D grades cow price is used as the cull cow price in this study.

4.3.1.3 Bred Heifer Prices

The Western Canada bred heifer prices are used as bred animal prices in herd expansions in this study. The price data series for the period of January 1990 to March 2003 in Canadian Dollars per head are obtained from CanFax.

4.3.1.4 Breeding Cow Prices

The monthly feeder cow price for the period of January 1976 to April 2004 contained in the monthly D grades slaughter cow prices data series represents the historical market price for cows if they are sold as feeder cows to processing plants rather than breeding animals to another herd for herd contractions. The AGDATA series number is #563 for the monthly feeder cow price. The price is in Canadian Dollars per cwt.

4.3.1.5 Hay Prices

Hay is the traditional source of forage in Alberta cow/calf operations. Most producers use combinations of hay and pasture in cow/calf production. The type of hay used in the cow/calf operation in this study is assumed to contain at least 50% of

[26] The D grades are for mature carcasses and are normally referred to as cow.

alfalfa. The monthly hay prices for the period of January 1976 to December 2003 are obtained from the Alberta Farm Input Prices, Agricultural Input Monitoring System (A.I.M.S.), Statistic and Data Development Unit, AAFRD. The prices are measured in Canadian Dollars per ton.

4.3.1.6 Other Costs

The 2004 Peace Lowland average cow costs constitute the other costs used in the cow/calf operation. Other costs are included into the equation on per cow per year basis and are shown in Table 4.3. The other costs portion is assumed to be independent of cow age and subject only to inflation as a non-stochastic component throughout the historical years. Since complete time series data for costs were not available for all of the historical years, the costs in 2004 are indexed back to year t dollars using CPI series for all goods.

$$P_{cost}(t+y) = \text{Other costs in } 2004 \times \frac{CPI_{(m,t+y)}}{CPI_{(Oct.2004)}} \qquad (4.9)$$

where $CPI_{(m,t)}$ is the consumer price index; m denotes the month in year t + y.

4.3.1.7 Production Inputs

The production input data for cow/calf operation in this study includes the probability of cow mortality, culling rate of the mature cows, weaning rate of the calves, and the variation in calf weights and cow weights in the context of cow ages, because the expected productivity of beef cows changes over their life spans. Data from Pang's study in 1997 provides probabilities for various outcomes (weaning, culled, or dead) for cows and relative weight of cows and their calves, by age group. The physical performance of the herd in this study is simulated by inserting the probabilities into the binomial distributions as specified in Section 4.1.1. Table 4.4 reports the expected probability of calf-weaning percentage, cow death rate, culling rates and relative calf weights and cow weights.

Based on the Regional Beef Cow/Calf Operation Profiles from AAFRD, the average weaning weight of all calves in Peace Lowlands area was 263 kg in 2004; cows' average weight was 550 kg. These numbers are used as baseline weights in the

calculation of absolute cow weights and calf weights for different age groups. A relative cow weight of 0.9 indicates that with mature cows averaging 550 kg in Peace Lowlands area, the absolute weight of a 2-year-old cow is 495 kg which is 550kg times the relative cow weight of 0.9. The absolute calf weaning weight from that cow is 234 kg which is the baseline 263 kg times the relative calf weaning weight of 0.89.

4.3.1.8 CPI Index

Full or complete time series data were not available for other costs per cow/year in the cow/calf operation. In such case, time series data was developed using price indexes. The Consumer Price Index (CPI) for all goods is used to convert nominal costs and returns from year 2004 into previous years. This monthly index for the period of January 1976 to April 2004 was obtained from AGDATA with series number #915.

4.3.1.9 Risk-free Rate of Return

The risk-free rate of return is a major variable in the valuation of option price. The calculation of the risk adjusted discount rate for the beef cattle operations using the capital market line in Section 4.1.3 would also require a determined risk-free rate.

A risk-free rate is the current rate of return for a one-year Treasury bill (Ross et al., 2002). The data of the auction yields rate of a one-year Treasury bill were obtained from the Bank of Canada's website. The calculated five-year average auction yields rate (2000-2005) of a one-year Treasury bill in Canada is 3.5% (Bank of Canada, 2005). This is used as the risk-free rate in this study.

4.3.2 Data Not Directly Available for the Cow/Calf Operation

The volatility of the returns of economic value of cows, the correlation between the returns of the economic value of cows and the cost of bred heifers/sales revenue of breeding cows as well as the dividend payout ratio cannot be obtained from secondary sources. Estimating volatility parameters for real option models is a matter of expertise and data. Conventional applications of option algorithms to real projects have used literature, publicly traded securities and historical data as sources for appropriate proxies of volatility and correlation of underlying real assets' returns.

However, these conventional sources may not be available for approximating the volatility and correlation regarding the economic value of cows for the spread option model in the cow/calf sector. The estimation of model parameters is accomplished by using computer software to simulate historical returns from the cows over the years from 1976 to 2004. One cash flow budget is created for each bred heifer/cow bought/sold in every month. Historical price series for calf, cow, bred heifer, hay and other costs as well as stochastic physical attributes of the cows caused by various distributional effects of production inputs entered the cash flow budgets to incorporate market and production risks. Monte Carlo simulation is performed with random draws from pre-specified distributions using the software package @RISK 4.5.2 (Palisade Corporation). The economic value of cows is obtained by summing up the discounted annual net cash inflows simulated throughout the life of the cows. The volatility and other model parameters are estimated from the series of simulated economic value of cows developed in the form of returns. The procedures of setting up the historical simulation model are discussed in detail in Chapter 5.

4.3.3 Data Directly Available from Sources for the Feedlot Operation

Although traditionally feeder cattle and live cattle futures can be used to establish prices on feeder cattle and fed cattle and therefore hedgeable profit expectation of feeding, actual profit determined by cash market price has an equal if not better explanatory power for feeder cattle placement decision in feedlot operations (Kastens and Schroeder, 1994). In this study, cash market prices for both feeder cattle and fed cattle are used instead of cattle futures price for the purpose of projecting profits at placement.

4.3.3.1 Feeder Cattle Prices

The feeder cattle prices used are the monthly average of cash market prices for 8-9 cwt. heifers and steers during the period of January 1976 to April 2004 in South and North Alberta. These data series are obtained from AGDATA with series number #643 and #599 for 8-9 cwt. heifers and steers, respectively. All prices are in Canadian Dollars per cwt.

4.3.3.2 Fed Cattle Prices

The monthly fed cattle prices used for the feedlot operation are the averages of high and low prices of live weight cattle sold directly to Alberta processing plants every month for the period of January 1976 to January 2004. Data series obtained from AGDATA with series number #278 contains monthly high and low direct sale prices for both Canada A/AA fed heifer and fed steer. All prices are in Canadian Dollars per cwt.

4.3.3.3 Production Costs

Production data for feedlot operations were obtained from the default values of FeederProfit$ v1.21[27] software and from the production economics branch in AAFRD. The unit cost of feed was extracted from the AgriProfit$ Technical Bulletin about the drylot backgrounding published by AAFRD. Data from "Guidelines for Estimating Feedlot Finishing Costs" published by MAF were used to determine feed intakes, yardage cost and other components of production costs for the feedlot operation. A breakdown of the total production cost of finishing a pen of feeder cattle is presented in Table 4.5.

4.4 Chapter Summary

This chapter discusses the additional methodologies of generating secondary data for the real option analyses in the cow/calf and feedlot operations. Emphasis has been given to the calculation of the economic value of cows in cow/calf herd expansion/contraction. Next, the chapter outlines the other data required for the real option valuation models in the cow/calf and feedlot operations. Table 4.6 provides a summary of data descriptions for data directly available from sources. Data including option model parameters that are not available from direct or secondary sources are identified. A historical simulation is described in Chapter 5 to estimate the remaining option model parameters for the real option models.

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[27] FeederProfit$ v1.21 is a computer software package that provide profit analysis for cattle producers developed by AAFRD in 2004. The default values in the demo version of FeederProfit$ are statistics collected from individual producers in the province of Alberta.

4.5 Tables for Chapter 4

Table 4.1 Data Required for Real Option Analysis in the Cow/Calf Operation and the Feedlot Operation

Data Required for Real Option Valuation Models	
Cow/Calf Operation	**Feedlot Operation**
Economic Value of Cows	**Feeder Cattle Price (800-900 lbs.)**
Calf Price	
Cull Cow Price	**Fed Cattle Price**
Hay Price	
Other Production Costs	**Weight of Feeder Cattle**
Weaning Rate	
Weaning Weight	**Weight of Fed Cattle**
Culling Rate	
Cow Death Rate	**Production Cost**
Cow Weight	Feed Cost and Yardage Cost
	Other Production Costs
Cost of Acquiring Bred Heifers	
Bred Heifer Prices	**Volatility of the Return of Feeder Price**
Sales Revenue of Breeding Cows	**Volatility of the Return of Fed Cattle Price**
Feeder Cow Prices	
	Correlation of Returns
Volatility of the Return of Economic Value of Cows	**Risk-free Rate**
Volatility of the Return of Bred Heifer Cost/Breeding Cow Revenue	**Dividend Payout Rate**
	Time to Maturity
Correlation of Returns	
Pasture Rent	
Dividend Payout Rate	
Risk-free Rate	
Time to Maturity	

Notes: Data printed in bold are direct model parameters; primary data printed in normal font are collected from sources to calculate the direct model parameters using additional methodologies described in Chapter 4. Definitions of the dividend payout ratio in the cow/calf and feedlot operations are specified in Chapter 5.

Table 4.2 Model Parameters for the Spread Option Valuation in the Feedlot Sector

Parameter	Parameter Description	
	Spread option	**Real option in feedlot operation**
S_1	Asset 1 price	Price of fed cattle
S_2	Asset 2 price	Price of 8-9 cwt. feeder cattle
X	Fixed conversion cost	Feed cost & Other production cost
w_1	Weight of asset 1	Output weight of a pen of fed cattle
w_2	Weight of asset 2	Input weight of a pen of feeder cattle
σ_1	Volatility of asset 1 price	Volatility of the return of historical fed cattle price
σ_2	Volatility of asset 2 price	Volatility of the return of historical feeder price
ρ	Correlation of two assets	Correlation of the returns of feeder cattle and fed cattle prices
r_f	Risk-free rate	Time value of money
t	Time to expiry	Production timeline of finishing a pen
δ	Dividend payout	Explicit cash payout by selling the fed cattle

Table 4.3 Other Costs per Cow/Year in the Cow/Calf Operation

Expenses	(per Cow/Year)		
	Bedding	$ 18.70	
	Pasture	$ 112.17	
	Vet & med	$ 19.78	
	Breeding & Bull	$ 0.88	
	Trucking & marketing	$ 15.33	
	Fuel	$ 14.51	
	Repairs – Machine	$ 14.72	
	Repairs- Buildings	$ 8.77	
	Utilities	$ 28.40	
	Custom Work	$ 8.63	
	Operating Interest	$ 5.85	
	Paid Labour	$ 8.44	
	TOTAL VARIABLE COSTS		**$ 256.18**
Fixed Cost (per Cow/Year)			
	Share/Lease Payments	$ 6.23	
	Taxes, Insurance	$ 8.83	
	Equipment & Building Purchases	$ 43.95	
	Equipment & Building Leases	$ 0.45	
	TOTAL FIXED COSTS		**$ 59.46**
	Total Other Costs per Cow/Year		**$ 315.64**

Source: Regional Beef Cow/Calf Operation Profile, AAFRD, 2004.

Table 4.4 Cow Productivity in Age Groups

Cow Age	Calving Year of Age	Weaning Rate	Relative Calf Weaning Weight	Absolute Calf Weaning Weight	Cull Prob.	Cow Mortality	Relative Cow Weight	Absolute Cow Weight
		%		kg	%	%		kg
2	1	75%	0.89	234.07	18%	2.1%	0.9	495
3	2	78%	0.97	255.11	16%	1.7%	0.95	522.5
4	3	85%	1.03	270.89	15%	1.2%	1	550
5	4	85%	1.06	278.78	16%	1.0%	1	550
6	5	91%	1.05	276.15	15%	1.0%	1.04	572
7	6	87%	1.05	276.15	17%	1.0%	1.05	577.5
8	7	82%	1.05	276.15	17%	1.6%	1.03	566.5
8+	8	80%	0.98	257.74	50%	5.2%	1.02	561
⋮	⋮							
8+	11	80%	0.98	257.74	50%	5.2%	1.02	561

Source: Pang, Hang. 1993. *Simulation Studies on the Effects of Cow Size, Milk Production and Calving Season on the Bioeconomic Efficiency of Beef Production.* Ph.D. Thesis, Dept. of Animal Science, University of Alberta, Edmonton, Alberta.

Table 4.5 Production Cost per Head in the Feedlot Operation Based on 2004

Feed Cost	**Unit Cost**	**Amount**	**$/head**
Rolled Barley	$ 138.72 /tonne	18.5 lbs/day	153.66
Barley Silage	$ 38.42 /tonne	12.5 lbs/day	28.75
Supplement	$ 330.4 /tonne	0.8 lbs/day	15.83
Total Feed Cost			**$198.24**
Other Operating Costs			
Straw	$ 37.62 /tonne	0.5 tons/feeder/years	6.17
Veterinary Medicine & Supplies			9.35
Yardage Cost	$ 0.35 head/day		46.20
Marketing & Transportation			31.54
Insurance			6.41
Death Loss			8.64
Labor Cost	$ 10 /hour	2 hrs head/year	7.23
Total Production Costs			**$313.79**

Notes: Days on feed is 132 days (0.36 year). Prices of feed are obtained from the 2002 Beef Drylot Enterprise-Average Pen Analysis published by AAFRD. Other numbers are estimated based on Guidelines for Estimating Feedlot Finishing Costs and Grassing Costs published by MAF.

Table 4.6 Data, Units, Notes and Data Sources

Data/Parameter	Unit	Notes	Data Sources
Calf price	$ / cwt.	monthly 5-6 cwt. heifer and steer cash market prices in Northern Alberta for 1976-2004	AGDATA, series number # 640 and # 567
Cull cow price	$ / cwt.	80% weight to D1, D2 price and 20% weight to D3 price for 1976-2004	AGDATA, series number # 563
Feeder cow price	$ / cwt.	monthly feeder cow cash market prices in Alberta for 1976-2004	AGDATA, series numbef # 563
Feeder cattle price	$ / cwt	monthly averages for 6-7 cwt.; 7-8 cwt.; 8-9 cwt. heifer and steer cash market prices in Alberta for 1976-2004	AGDATA, series number #641, #642, #643 for heifer; #568, #571, #599 for steer
Fed cattle price	$ / cwt.	monthly direct sale prices for A1/2 fed heifer and steer in Alberta for 1976-2004	AGDATA, series number # 278
Bred Heifer price	$ / head	Western Canada bred heifer prices for 1990-2004	CanFax, Western Canada bred heifer price
Hay Price	$ / ton	monthly hay prices for 1976-2003	Alberta Farm Input Prices, Agricultural Input Monitoring System (A.I.M.S.), Statistic and Data Development Unit, AAFRD
Consumer Price Index		monthly index for 1976-2004	AGDATA, series number # 915
Other Cost of production	$ /cow /year	2004 Peace Lowland, AB average cow costs in cow/calf enterprises	Regional Beef Cow/Calf Operation Profile
Average weaning weight	kg	263 kg in Lowlands area in 2004	Regional Beef Cow/Calf Operation Profile
Average cow weight	kg	550 kg in Lowlands area in 2004	Regional Beef Cow/Calf Operation Profile
Average herd Size	head wintered	123 head in Peace Lowland cow/calf enterprises	Regional Beef Cow/Calf Operation Profile
Investment in pasture land	$ /cow	$60.41 in Peace Lowland cow/calf enterprises	Regional Beef Cow/Calf Operation Profile

Notes: Average weights of weaned calf and cow are used to calculate the absolute weight using the relative weight provided in Table 4.4.

Chapter 5: Historical Simulation and Model Parameters

Applications of the real options approach often rely on simulation models to calibrate the model parameter values. This chapter discusses how the parameters for real options analysis in the decision to expand/contract herd size in cow/calf operations are generated from the simulated economic value of cows. Next, the performance of the historical simulation model is validated. Finally, the key model parameters of the real option valuation model in the feedlot operation are calculated.

5.1 Historical Simulation of the Economic Value of Cows

The historical simulation model uses the historical data series outlined in Chapter 4 to simulate the cash flows and economic values associated with the beef cows bought/sold every month in the breeding herd expansion/contraction starting from January 1976. The base case model which simulates the cash flows and economic value of a single beef cow is adapted from a model developed by Dr. Brian Radke, Economist for AAFRD. Based on the discussion of the size of expansion/contraction in the cow/calf operation in Section 4.1.2, the base case model is revised to accommodate 10 to 20 cows in cow herd expansions/contractions.

The distributional effects of weaning rate, culling rate, and death rate result in stochastic variations in the physical attributes of the group of cows such as the number of calves weaned, the number of cows died, and the number of cows culled. These physical attributes affect the estimation of the economic value of cows through revenues, costs and net cash flows every production year. Due to the lack of data to clarify the nature of the relationship between the production timeline and the costs, it is assumed that cow deaths and costs are uniformly distributed over the production year. Following Trapp's study, expected annual winter feed cost and other production costs are reduced by 50% for the portion of cows that die and by 25% for the portion of cull cows.

Using the computer program @RISK 4.5.2, Monte Carlo simulation with 5,000 iterations per simulation was performed to simulate the physical attributes of the cows as random draws from the binomial distributions specified in Section 4.1.1 over the historical years. The net cash flows in Equation 4.6 became:

$$NCF(t+y) = (\tilde{N}_{calf}(t+y) \times \$P_{calf}(t+y) \times W_{calf}(y) + \tilde{N}_{cow}(t+y) \times \$P_{cow}(t+y) \times W_{cow}(y) - \$P_{hay}(t+y) \times H_{cow}(y) \times (1 - .5 \times \tilde{N}_{die}(t+y) - .25 \times \tilde{N}_{cow}(t+y)) - \$P_{cost}(t+y) \times (1 - .5 \times \tilde{N}_{die}(t+y) - .25 \times \tilde{N}_{cow}(t+y)))/(1+r)^{y} \quad (5.1)$$

And $$S_{1,t-12} = \text{Total Net Cash Flow}_{t-12} = \sum_{y=1}^{a-1} NCF(t+y) \quad (5.2)$$

"~" denotes a stochastic process; t-12 is the date (month & year) the cow is purchased/sold for herd expansion/contraction; t-12 = Jan 1976, ..., Apr 1997. y is defined as the calving year of age in Table 4.4; r is the discount rate. N's are the stochastic outcomes (weaning, cull, death); W's are the weights of calves and cows as deterministic functions of calving year of age; H is cow's hay intake depending on calving year of age; P's are the historical price series for calf, cow, hay and other cost respectively. $S_{1,t-12}$ is the economic value of cows. A twenty-two year historical series (1976-1997) of monthly economic values of cows was simulated using the historical price series for the period of 1976 to 2004 and the random draws from the binomial distributions of production inputs.

It is noted the various 1976-2004 price series provided data for economic values of cows for only 1976-1997, because calculating economic values for the 1998 cows with 6 more years of production left would require prices from 1999 through 2005. Similar to the previous studies (Hughes, 1999; Ibendahl et al. 2004), all the prices used are nominal. The cow and calf prices on the revenue side and the price of hay as feed cost on the cost side all affect the net income. Therefore, the effect of inflation is likely to be minimized by affecting both revenue and cost and by discounting the net annual income.

The standard deviation of the annual return of the underlying cow/calf operation based on 100 cows from 1977 to 1993 Monte Carlo simulation is calculated to be 12.8%. This result is compared with Munro's historical study in 1993. In his study, the standard deviation of an Alberta weaned calf enterprise's annual return was 14.63%. So the calculated standard deviation of 12.8% from the simulated returns is considered an appropriate measure of volatility for the local cow calf operation. The calculation of the return using the Capital Market Line is given by:

$$3.5\% + 12.8\% \times \left(\frac{7.09\%}{16.48\%} \right) = 9.01\%$$

The calculated 9.01% expected return which includes a risk premium to compensate producers for bearing risk would be used as the discount rate for the cow/calf operation. Bauer (1997) analyzed the cost and return of a Southern Alberta cow/calf operation based on actual data from 1976-1996. The nominal rate of return for a cow/calf operation was found to be 8.2%, with a standard deviation of 21.3%. Using Bauer's risk level in the above CML calculation would come up with a discount rate of 12.66%. This would suggest the 9.01% discount rate seemed to understate the risk. However, comparing with the 8.2% rate of return from Bauer's work, the 9.01% expected return had been adjusted for a higher risk premium. An approximately 9% discount rate is commonly used in literature regarding present value calculations in cow/calf operations (e.g. Hughes, 1999; Ibendahl et al, 2004) and is therefore deemed appropriate to be used in determining the economic value of cows for the spread option model in the cow/calf operation.

5.1.1 Simulation Model Validation

Assuming there are 100 cows in the herd expansion, historical series (1976-1997) of annual net cash inflows and economic values of the cows were simulated. The standard deviation of the net cash inflows generated by these 100 cows was compared with the AAFRD results. AAFRD produced provincial average of cow/calf enterprise return to asset from 1989 – 2000 based on actual producers' returns. AAFRD standard deviation in annual net cash inflows was $10,099.5 for 100 cows without allowing inventory adjustments to herd size changes. The standard deviation of annual net cash inflows from the 100 cows bought in 1989 in the simulation model over the same production time period, keeping production variations at their expected values, ranged from $8,880.3 to $9,941.3 for 100 cows.

Although the nominal annualized IRR of a 100 cow operation from Bauer and Novak's study in 1993 was calculated using a different measure, a comparison is still made between Bauer's results and the results from the simulation model. Bauer used historical prices to simulate the cash flows of a single herd from 1979 –1989 and

calculated the annualized internal rate of return over the twelve month period based on the monthly change of cash flows. The purpose of Bauer's model is to constitute an annual rate of return using the annualized IRR. However, the IRR calculated from the simulation model in this study was earned over the whole life spans of the cows bought during 1979-1989. Care should be taken in interpreting the two IRRs. The nominal mean IRR of the 100 cows bought during the period 1979-1989 from the simulation model in this study is 14.17% with a standard deviation of 8.11% whereas the resulted mean IRR from Bauer's work was 13.99% with an 11.91% standard deviation.

It can be concluded the simulation model performs adequately in generating historical returns of cows. However, one major deficiency of the historical simulation model needs to be pointed out. The simulated economic values of cows do not take into account the value of the retained heifer calves produced by the cows for maintaining herd size. Although retaining heifers forgoes current sales of calves, the value of the retained heifers is usually greater than the sales price of heifer because retained heifers can generate greater value through sales of offspring in the succeeding years. Since the cows have up to 12 years of life, the value of the retained heifer from the calf crop in the long-run should be captured by their economic values. However, it is difficult to measure the value of all the retained heifers from each year's calf crop over the life of the cows. Therefore, the simulated economic value of cows may understate the actual economic value of cows in the herd expansion or contraction.

5.1.3 Calculating Volatility and Correlation from the Simulated Results

A historical series (1976-1997) of economic values of 10 to 20 cows for herd expansion/contraction bought/sold per month was simulated from the historical data series for the period of 1976 to 2004 and the draws from the binomial distribution of the biological probabilities. Similar to the financial markets, historical returns provide a potential indicator of the risk associated with the underlying asset (economic value of the cows) suggested by Wilmott (2001).

In standard option pricing models, the geometric annual return u_{t-12} is calculated from:

$$u_{t-12} = \ln\left(\frac{S_{t-12}}{S_{(t-1)-12}}\right) \tag{5.3}$$

where S_{t-12} is the simulated economic value of the cows at time t-12; $S_{(t-1)-12}$ is the economic value of the cows bought in the same month a year ago. An estimate, sd, the standard deviation of the u_t's is given by (Hull, 2002, pp. 237):

$$sd = \sqrt{\frac{1}{n-1}\sum_{t=1}^{n} u_t^2 - \frac{1}{n(n-1)}\left(\sum_{t=1}^{n} u_t\right)^2} \tag{5.4}$$

The volatility of the return of the economic value of cows σ_1 can be estimated as $\hat{\sigma}_1$, where

$$\hat{\sigma}_1 = \frac{sd}{\sqrt{T}} \tag{5.5}$$

The standard time interval T is one year.

The above described procedures can be applied to the historical series of the price of bred heifers in Section 4.3.1.3 to generate the volatility of return of bred heifer costs $\hat{\sigma}_2$. In a herd contraction, assuming that cows are not resold as breeding animals $\hat{\sigma}_2'$ is the volatility of the return of the revenue from feeder cow sales. $\hat{\sigma}_1'$ is the volatility of the return of the forgone economic value of cows sold.

In herd expansions, the correlation between the geometric annual returns of the economic values of cows and the costs of cows purchased as bred heifers can be obtained using the standard statistical procedure. However, it requires paired observations of monthly prices of bred heifer and the economic values of cows purchased monthly starting from January 1976. Due to the constraint of data availability of bred heifer prices for earlier years, 5-6 cwt. heifer calf prices for the period of January 1976 to April 2004 are used as a proxy to facilitate the correlation calculation. The 5-6 cwt. heifer price series has a correlation of 0.85 with Western Canada bred heifer prices from January 1990 to March 2003.

In order to approximate the monthly bred heifer prices per head for the earlier years based on the monthly 5-6 cwt. heifer price per cwt., the Western Canada bred

heifer prices (per head) for the period of January 1990 to March 2003 were regressed on the 5-6 cwt North Alberta heifer calf prices during the same period using a simple OLS regression without constant. Reported in Table 5.1, the estimated coefficient is 8.0 with an R square of 0.68. The accuracy of the estimated bred heifer prices from the simple regression was tested by comparing the estimated prices with the actual bred heifer prices. The estimated bred heifer prices for the period of January 1990 to March 2003 using the linear regression model have a mean of $881.53 per head with a standard deviation of $168.1 while the actual Western Canada bred heifer prices during the same period have a mean of $892.2 per head and a standard deviation of $170.87. So the bred heifer series estimated from the 5-6 cwt. North Alberta heifer calf prices constitutes an appropriate proxy of historical bred heifer price series.

In herd contractions, the correlation is calculated between the geometric annual returns of the market price of feeder cows and the returns of the forgone economic value of cows. Since the historical data series for feeder cows is complete, the correlation can be calculated directly.

5.1.4 Calculating Discrete Dividend

In the financial option case, many underlying assets are assumed to pay dividends in one of the two forms. The first form is where the underlying asset pays a continuous dividend yield. In this case a fixed annual dividend rate is determined as a percentage of the value of the underlying asset (Hull, 2002). The second form is where the asset pays a discrete known dividend yield at a certain time period. Dividends affect option values through their effects on the underlying asset value. Because the asset value is expected to drop by the amount of the dividend on the ex-dividend date, high dividends imply lower call premiums and higher put premiums.

Many real assets have leakages in value which are of the same nature with dividends, in the form of explicit cash flows (rental, interest, etc.) or implicit benefits (convenience yield[28]) (Amram and Kulatilaka, 1999). An adjustment of dividend must be made to the real option valuation so as to value the option value correctly.

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[28] The return to holding the commodity net of storage costs is the convenience yield.

It is assumed that the cow/calf operation has a discrete known dividend payout every production year. Following Copeland and Antikarov (2001, pp. 252), "the annual dividend during the life of the option is based on a per period basis depending on the free cash flows generated each year".

Hughes (1999) defined family living draw as a form of cash payout from the free cash flows generated by cows in the cow/calf operation. A proxy of $125 family living draw including unpaid labor and management charge is assumed to be paid out from the net cash inflows of each cow in 2004. This amount is calculated from the Regional Beef Cow/Calf Operation Profile to account for unpaid labor and management costs during periods of winter feed and summer pasture. The rest of the positive net cash flow from the cows is available to the producers for savings, personal consumption, and taxes. All positive cash flow is paid out to producers when the annual net cash flow is less than the family living draw. The operation pays no dividend in periods with negative net cash flows. The amount of dividend is subject to inflation throughout the historical years. The $125 family living draw in 2004 was indexed back to year t dollars using CPI for all goods.

The dividend payout ratio in production year y is calculated by dividing the inflation adjusted family living draw by the estimated economic value of the cows which is the sum of the discounted net cash flow from year t + y to perpetuity[29]. The annual dividend payout ratios from the cows during eleven production years are calculated for cows bought or sold in herd expansions or contractions during the period of 1990 to 1997. The average of these discrete dividend payout ratios is used as a proxy of the continuous dividend ratio of the economic value of the cows to simplify the option valuation.

5.2 Model Parameters of the Spread Option in the Cow/Calf Operation

Historical simulation-based procedures generated estimates of the economic value of cows in the expansion/contraction over the historical years. Geometric annual returns and the spread option model parameters were calculated from the

[29] For details in calculating the dividend payout ratio, please refer to Copeland and Antikarov, 2001, pp 252.

simulated economic value of cows. Three sets of model parameters were presented for different types of herd expansion/contraction: 1) unit expansion/contraction in all months (from January to December), 2) multiple unit expansion/contraction with 10 cows and 20 cows in all months, 3) multiple unit expansion/contraction with 10 cows and 20 cows in October, November and December. The first and second sets of parameters were compared to test the effect of diversification of multiple assets expansion/contraction in contrast to a single asset expansion/contraction. The third set is similar to real world cow/calf operations in Alberta because the calves/cows most likely would be sold/bought as weaned calves/bred heifers in October, November and December. Therefore the third set of parameters is used to calculate the underlying spread option values. Parameter estimates are shown in Table 5.2.

As would be anticipated, results in the first two sets of parameters indicate that as the size of the expansion/contraction increases, the returns from the economic value of cows in the expansion/contraction become less volatile. An expansion of 20 cows can cause a rapid drop in volatilities of return from the expected economic values, from 79% of a unit expansion to 23 %. The differences in volatility of the return of economic values could be reduced by increasing the number of animals in the expansion/contraction because multiple units in the expansion/contraction can help diversify the production risks such as calf morbidity, cow death and morbidity. It is also true that the dividend payout ratio increases with the size of herd expansion/contraction. Generally, volatilities of return from the economic value of cows increase whereas dividend payout ratios decrease in the third set of parameters due to the volatile market with high-volume weaned calves from October to December. In Table 5.2, the dividend payout ratios in the herd expansions were slightly higher than those in herd contractions due to the difference in calving age between bred heifers and older cows. There was likely a negative correlation between the returns of the economic value of cows and the cost of bred heifers/revenue from selling cows in herd expansion/contraction. However, most correlations are statistically insignificant. Therefore, the negative correlations may only have limited contributions to the magnitude of the option values.

For the spread option analysis, simulated economic values of cows and costs of bred heifers were assumed to follow geometric Brownian motions. Over discrete periods of time, the distribution of the underlying real asset value at a future time t, given the initial economic value at time zero, is approximately lognormal (Dixit, 1992b). The lognormal distribution is asymmetric, positively skewed, and most significantly assumes that the factor being modeled cannot go negative. In the cow/calf operations, the assumption that the economic value of cows and the cost of bred heifers/sales revenue of cows can not take negative value is reasonable. However, the spread can be positive or negative depending on which asset value is greater. To observe the distribution of the simulated economic value of cows, simple random sample distributions of the logarithm of economic values of 10 cows and 20 cows simulated with a single iteration were illustrated in Figures 6.1-6.2. It is concluded that the normally distributed logarithm of economic values over time in the random sample distributions is consistent with assuming lognormality and geometric Brownian motions.

5.3 Model Parameters of the Spread Option in the Feedlot Operation

Asset Values and Volatilities of Assets

As shown in Table 4.1, the purchase price of the feeder cattle is the price of the 8-9 cwt. feeder cattle price. The selling price is the price of 12.5 cwt. fed cattle price. Using the cattle prices on June 30th, 2005 as the best price estimates, the selling price of the fed cattle and the purchase price of the feeder cattle constitute the two baseline asset values in the payoff function of the spread option.

The two risky assets in the payoff function of the spread option are driven by stochastic fed cattle price and feeder cattle price. The volatility of 8-9 cwt. feeder cattle price is 16.85% using Equation 5.4 for the period of 1977 to 2004. The volatility of fed cattle price amounts to 14.43% during the same period. The correlation between the rates of return of two prices is 0.783. The calculated volatility rates and correlation of returns of historical prices may constitute appropriate proxies for the volatility and correlation parameters for the spread option analysis in the feedlot sector.

Weights of Assets

Assuming that the pen of 150 feeder cattle (a 50% steer and 50% heifer mix) brought into the feedlot are of uniform weight of 850 lbs., the total input weight of a pen of feeder cattle is given by: 850 × 150 = 1,275 cwt. The average finished weight of fed cattle is 1,250 lbs (1,350 lbs for steer and 1,150 lbs for heifer). Taking into consideration the 1% feeder cattle mortality rate and the 4 % finished percentage shrink, the output weight of a pen of fed cattle totals 1,781.25 cwt.

Production cost

The feed ration in Table 4.5 can provide an ADG of 3 lbs/day. Therefore the time on feed in the feedlot is about 132 days or 0.36 year. Feed cost, yardage, labor, trucking and all other costs were allocated among a pen of 150 feeder cattle in Table 4.5. It is assumed the $313.79 total production cost per head for finishing which includes feed cost and yardage cost is used as a fixed unit cost in the spread option valuation. The total fixed cost is given by: $313.79 × 150 = $47,068.5 for the entire pen of cattle.

Dividend Payout Ratio

It is assumed the pen of fed cattle in the feedlot operation carries a dividend-like payout associated with selling cattle. The payout can be considered as a premium that comes from the buyer-preferred color and breed or high quality beef and use of healthy diets. Therefore, it may be reasonable to set a dividend payout ratio of finishing the feeder cattle. The dividend payout ratio is assumed to be 5%. The choice of the dividend ratio can be calibrated with sensitivity analysis. All the above discussed parameter values for the spread option are summarized in Table 5.3.

5.4 Chapter Summary

This chapter focused on determining the parameter values for the real options valuation in the cow/calf operation and the feedlot operation. This began by first explaining the procedures of setting up the historical simulation model to generate historical economic value of cows in herd expansion or contraction in the cow/calf operation. Both the stochastic production components and historical prices were combined in the Monte Carlo simulation model to produce the economic value

estimates. Based on the simulation results, volatility and correlation parameters were calculated. Explicit dividend measured by family living draw from the annual free cash flows generated by cows was also incorporated into the simulation to come up with the dividend payout ratio of the economic value of cows. Assumptions were made to facilitate the real option valuations in the feedlot operation. The calculation of model parameters were based on generalized assumptions about the underlying cattle feeding operation.

5.5 Tables for Chapter 5

Table 5.1 OLS Estimates for Western Canada Bred Heifer Prices

Variable	Coefficient	Std. Error	t-ratio
Intercept	0	N/A	N/A
5-6 cwt. heifer price	8.0499	0.0682	118.014*

N=160, $R^2 = 0.68366$, $\overline{R}^2 = 0.67728$
"*" stands for statistically significant at 1% level of significance.

Table 5.2 Parameter Estimates for Beef Cow Herd Expansion/Contraction from the Historical Simulation

Set of Parameters	Expansion/Contraction Decisions	σ_1	σ_2	ρ	δ
		%	%		%
First Set	Unit Expansion	78.70%	21.49%	-0.0218	5.46%
	Unit Contraction	64.49%	21.81%	-0.0064	4.06%
Second Set	Expansion with 10 cows	31.20%	21.49%	-0.0809	7.63%
	Contraction with 10 cows	28.58%	21.81%	-0.0309	4.63%
	Expansion with 20 cows	22.60%	21.49%	-0.1156*	7.75%
	Contraction with 20 cows	23.90%	21.81%	-0.0356	4.54%
Third Set	Expansion with 10 cows	32.70%	16.57%	-0.037	7.07%
	Contraction with 10 cows	29.69%	23.49%	0.0399	4.17%
	Expansion with 20 cows	23.70%	16.57%	-0.0526	7.23%
	Contraction with 20 cows	24.80%	23.49%	0.0505	3.97%

Notes: The parameters are defined as following: σ_1 = volatility of return from expected economic values of cows in expansion/ forgone economic values of cows in contraction, σ_2 = volatility of return from cost of bred heifers in expansion/revenue of feeder cows in contraction, ρ = correlation of returns, δ = continuous dividend payout ratio from the economic value of cows. "*" stands for statistically significant correlations at 10% level of significance. The critical t-statistic was 1.645 for the t-test $t = \rho\sqrt{(n-2)/(1-\rho^2)}$ where n is the number of observations at 10% significance level (Steel and Torrie, 1980).

Table 5.3 Summary of Parameters for the Spread Option in the Feedlot Sector

Parameter	Parameter Description		
	Spread option	**Real option in feedlot operation**	**Value**
S_1	Asset 1 price	Price of fed cattle (Alberta direct sale) on June 30th, 2005	$82.47 / per cwt.
S_2	Asset 2 price	Price of 8-9 cwt. feeder cattle in Alberta on June 30th, 2005	$103.15 / per cwt.
X	Fixed conversion cost	Feed cost & Other production cost	$47,068 / pen
w_1	Weight of asset 1	Output weight of a pen of fed cattle	1,781.25 cwt. / pen
w_2	Weight of asset 2	Input weight of a pen of feeder cattle	1,275 cwt. / pen
σ_1	Volatility of asset 1 price	Volatility of the return of historical fed cattle price	14.43 %
σ_2	Volatility of asset 2 price	Volatility of the return of historical feeder price	16.85 %
ρ	Correlation of two assets	Correlation of the returns of two assets	0.783
r_f	Risk-free rate	Time value of money	3.5 %
t	Time to expiry	Production timeline of finishing a pen	0.36 year
δ	Dividend payout	Explicit cash payout by the fed cattle	5 %

Notes: June 2005 prices were obtained from CanFax Daily Market Report; Fed cattle price on June 30th 2005 is assumed to be the best price estimate for calculating sales revenue of fed cattle in the feedlot operation.

5.6 Figures for Chapter 5

Figure 5.1 Random Sample Distribution of Log Economic Value of 10 Bred Heifers

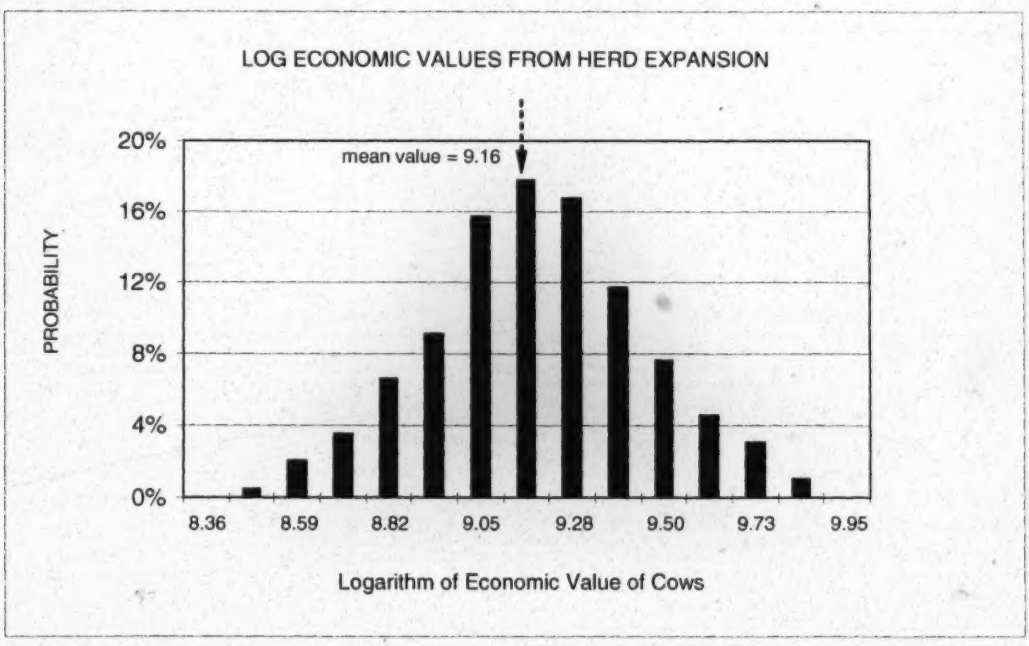
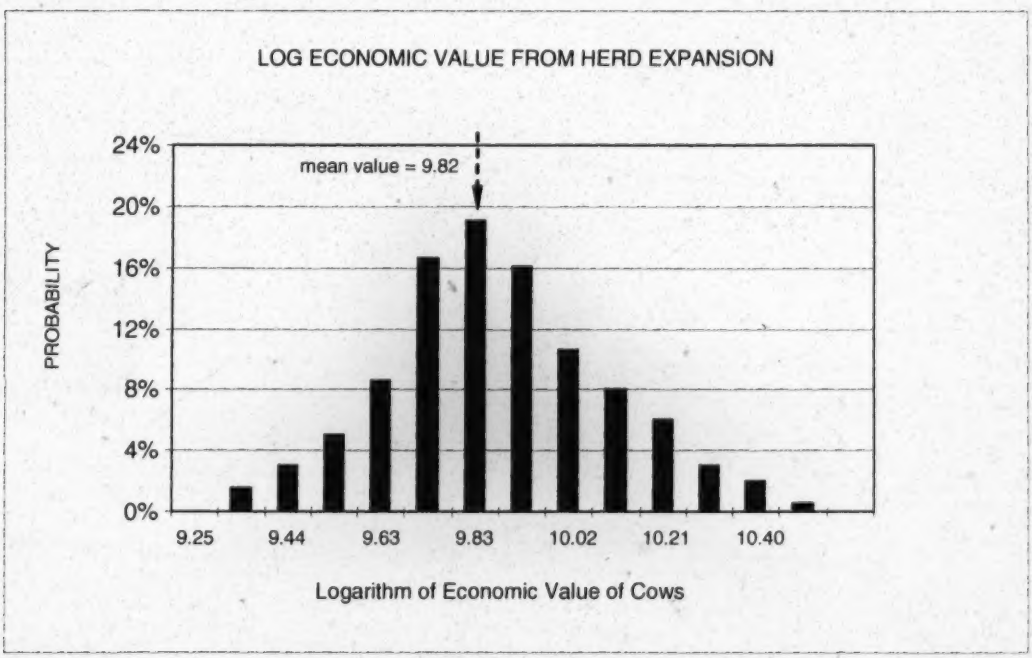


Figure 5.2 Random Sample Distribution of Log Economic Value of 20 Bred Heifers



Chapter 6: Results and Analysis of Real Options Models

This chapter reviews the results from the real options models in the cow/calf and feedlot operations. Real option values are then used to measure the effect of irreversibility and uncertainty on investment decision making. It is evaluated whether real option values can alter the decisions made under a conventional NPV framework based on input prices under different scenarios. Real option valuation models are also analyzed to determine the threshold values which can aid future investment policy[30] design for individual cow/calf operations. The overall applicability of the real option models in the investment decision making in the cow/calf sector and the feedlot sector will be discussed respectively.

6.1 Results in the Cow/Calf Operation

Estimation of model parameters for the spread option valuation model was accomplished by a historical simulation of economic value of cows. Spread option values are calculated using the estimated parameters. Next, the direction of real option influence on the decision to expand or contract herd size made under the NPV framework is discussed. Implications for investment policy associated with the decision of changing herd size within a specified period of time can be drawn from the expansion/contraction thresholds extracted from the option model. Finally, the applicability of real option models in the cow/calf sector is evaluated.

6.1.1 Simulated Historical Profit/Loss Associated with Changing Herd Size

This section presents the simulated profit/loss of herd expansion and contraction from the historical simulation model. The expected economic value of cows was simulated using the expected values of the outcomes from distributions of production inputs of cows and historical price series. The profit/loss results were calculated using the expected economic value of the cows less the cost of purchasing the cows as bred heifers in herd expansions. In herd contractions, the profit/loss results were calculated using the sales revenue of cows less the forgone economic value of the breeding cows. Beef cow producers should add bred heifers whenever

[30] The investment policy refers to the guidelines for future investment decision making within the underlying cow/calf operation.

there was a positive profit in herd expansions and sell breeding cows when herd contractions resulted in positive profits.

The historical profit/loss results of herd expansions of 10 and 20 cows as well as contractions of 10 and 20 cows were reported in Tables 6.1-6.4. Descriptive statistics were calculated for each table.

Based on results in Table 6.1, positive NPVs of expanding with 10 cows occurred in mid 70's and from mid 80's to early 90's. A total of 112 months out of 208 month during 1976 to 1993 generated positive profits for producers to expand the herd size. The mean of the profit/loss results was $486 with a standard deviation of $1,597.23. The highest profit $4,526 occurred in February 1978 while the largest loss was -$2,516 in January 1980. As shown in Table 6.2, positive profits of expanding with 20 cows occurred in the similar time periods as the expansion of 10 cows, but at a lower frequency, 94 months out of 208 months. The mean of the profit/loss results was $497.5 with a standard deviation of $3,149.5. The largest profit and loss were $8,716 in February 1978 and -$5,242 in January 1980, respectively. It is observed, with more cows in the expansion, a wider range of profits/losses with a large standard deviation is generated. Although adding more cows in the herd expansion can help diversify the production risks such as calf morbidity, cow death and morbidity so as to reduce return variability, it lowers the average profitability of the cows and thus requires more caution in doing so.

The designated breeding cows for herd contractions range from 6 year old cows to 10 year old cows. Based on results in Table 6.3, positive profits from contraction of 10 cows occurred in early 80's and 1993 to 1995. A total of 54 months out of 256 months (1976-1997) in which contractions resulted in positive profits were suggested by the profit/loss results. The mean of the profit/loss results was -$1,304.77 with a standard deviation of $1,865.61. The largest profit $2,962.28 occurred in May 1994 while the largest loss was -$6,386.64 in February 1978. The positive profits from contraction of 20 cows occurred in the very similar time periods as the contraction of 10 cows, but at a higher frequency, 78 months out of 256 months. The mean of the profit/loss results was -$1,404.68 with a standard deviation of $3,632.18. The largest profit and loss were $6,928.32 in May 1994 and -$11,797 in January 1978.

With more cows in the contraction, the production risks such as calf morbidity, cow death and morbidity associated with the foregone economic value of cows are diversified. However, the diversification is at the expense of incurring a lower average forgone economic value of cows. Since the profits from herd contractions were calculated using the sales revenue of cows less the expected forgone economic value of the cows, it is more likely to gain profits from larger scale contractions of older cows than from small contractions.

Figures 6.1-6.4 provide insights into the historical herd expansion/contraction pattern based on the above profit/loss results. All the positive profits were indicated by areas above the x-axis. A positive profit along the x-axis suggested that herd size should be expanded or contracted accordingly. The figures for the herd expansion/contraction decision were compared to the actual changes of beef cow population on Alberta farms from 1970 to 1998 (Figure 6.5). As shown in Figure 6.5, two peaks of beef cow population occurred in 1974-1976 and 1994-1996. Prior to these periods, the entire population of the provincial beef cow herd was expanding quickly. As indicated by Figures 6.1-6.2, it was profitable to expand the herd size in mid 70's and late 80's to early 90's. Two valleys of the provincial beef cow population happened in 1986 and after 1995. Figure 6.3 and 6.4 clearly showed that early 80's and 1995-1996 were the two profitable periods to contract herd size. The only noticeable difference was that the profit/loss results suggested that the expansion of herd size lasted until late 70's and the contraction of herd size be carried out earlier than 1995, starting from the second half of 1993. Overall, decisions of changing herd size based on the simulated profit/loss were consistent with what was observed in the past.

6.1.2 Real Option Results in the Cow/Calf Operation

The base case scenario for the real option analysis is based on the prevailing market prices in 2005. Assuming cattle prices observed in April 2005 are the best price estimates for the succeeding years, the NPV and real option values associated with herd expansion/contraction can be calculated. Other representative scenarios with different set of prices under different market conditions for the real option

analysis in the cow/calf sector are selected. A list of different scenarios we consider is given as follows:

- Scenario 1 – Base Case (April 2005)
- Scenario 2 – Best case (year 2000[31])
- Scenario 3 – Pre-BSE[32] (2002 - May 2003)
- Scenario 4 – Post-BSE (June 2003 - April 2004)

The input prices under different scenarios are listed in Table 6.5.

Base Case Scenario

Keeping stochastic outcomes from distributions of production inputs at their expected values, the market prices observed in April 2005 were used as price estimates to calculate the estimated net cash flows and the economic value of cows using Equations 5.1 and 5.2. Under the NPV framework, the NPV of herd expansion or contraction were calculated as the economic value of the cows less the initial cost of purchasing the bred heifers or as the sales revenue of cows less the forgone economic value of the cows. Beef cow producers should add bred heifers whenever the NPV results in herd expansions are greater than zero and sell breeding cows when the NPV results in herd contractions are greater than zero. The NPVs for herd expansions and contractions were calculated and listed in Table 6.6.

Both NPV results in herd expansions were associated with negative values (-$2,724 and -$6,110) and were unattractive for cow/calf producers to expand herd size. The negative NPV results were caused by the negative BSE impact on prices, such as the closure of export markets. Comparing with other scenarios, the calf price, on average, was 20% and 8% lower than the calf price in Scenario 2 (year 2000) and 3 (2002- May 2003). Although the calf price was 12.7% higher than the price in Scenario 4 (June 2003-April 2004), it did not change the negative NPV results and therefore the decision was do not expand. For the case where herd contraction was considered, the NPV for contraction with 10 cows was -$388 whereas the NPV for

[31] According to beef specialist, 1999 was the first year that every sector in the cattle industry was profitable and the overall performance of the cattle industry was even better in year 2000. The entire population of cows on Alberta farms expanded in 2000 (Figure 6.5).

[32] The discovery of bovine spongiform encephalopathy (BSE) - commonly called mad cow disease in one cow in northern Alberta on May 20, 2003 has had an enormous economic impact on cattle industry and cattle producers due to the closure of export markets.

contraction with 20 cows was $175. Hence, regardless of the uncertainty associated with future market conditions, the positive NPV suggested that contraction of herd size by 20 cows would be in the best interests of cow/calf producers in 2005.

The next set of results in Table 6.7 concern the real option values inherent in the expansion/contraction decisions which allow the producer to take actions later when uncertainty is resolved to some extent. Option values and exercise patterns were determined by a modified version of Haug's numerical method edited by the authors to allow Bermudan exercise features in every October, November, or December to buy/sell bred heifers/breeding cows. The investment opportunity of manipulating herd size were assumed to last for 10 years which implied a 10 year time to maturity of the real options. In Table 6.7, the option values associated with the decision to contract were larger than those with the decision to expand because initially the underlying spread in the decision to expand is largely out of the money. Real option values generally increase with the time to maturity.

Standard real option theory states that the investment value with the flexibility of waiting under uncertainty for a real project with irreversible expenditure is equal to the expected return under the NPV framework plus the option value to wait (Copeland and Antikarov, 2001; Luehrman, 1998). The general decision rules when the flexibility of waiting has been properly taken into account under the real options framework are:

- If a negative NPV plus the option to wait value is greater than zero, do not reject the investment immediately.
- If a positive NPV is lower than the option to wait value, wait for more market evidence before invest.
- If a positive NPV is greater than or equal to the option to wait value (adequate to cover the option to wait), investment should start right away.

In the base case scenario, expanding the herd size would not appear to be economically feasible under the prevailing market prices in 2005 since the NPVs (-$2,724 for 10 cows; -$6,110 for 20 cows) plus the option to wait values in 10 years ($474.9 for 10 cows; $402 for 20 cows) were still negative. On the other hand, the positive NPV result in herd contraction must exceed the corresponding option value

of waiting associated with herd contraction before selling breeding cows, taking uncertainty and irreversible costs into consideration. When there was no flexibility available, the decision was to contract the herd size by 20 cows immediately as a result of the positive NPV. However, when real option value is considered, the herd is contracted only if the expected NPV is sufficient to cover the forgone option value of waiting. Since the NPV result for the contraction of 20 cows ($175) was less than the option to wait values in 1 year ($1,380.5), the contraction decision was altered by the flexibility to postpone the decision. The decision under the prevailing cattle prices in 2005 thus became to wait for at least 1 year when there may be more market information. Interpretation of the decision rule of herd contraction after taking the $1,380.5 option to wait value into account revealed that unless the calf price drops to $112.02 per cwt. or feeder cow price goes up to $44.24 per cwt. in 2005, keeping all other variables the same, herd contraction should be postponed. This may provide one possible explanation as to why there was no observed major herd contraction in Alberta in 2005[33] despite the low cattle prices caused by BSE.

An important purpose of this study is to determine the investment policy for the underlying cow/calf operation which includes the thresholds and timings of varying herd size under future uncertainty. The implications for investment policy design can be found from the spread option model. By extracting the early exercised nodes in the three-dimensional spread option structure, insights with regard to investment policies such as under what circumstances should cow herd be expanded or contracted in a future time period can be gained. The area of the paired asset threshold values associated with the investment policies for expansion and contraction of 10 cows in the next 2 to 3 years (year 2007 to year 2008) were graphically portrayed in Figures 6.6-6.9 respectively.

Based on Figure 6.6, the shaded area was representative of the possible asset value combinations in year 2007 for an expansion of 10 cows. From the right border of the area for expansion, the expansion thresholds can be drawn accordingly. Generally, the economic value of 10 cows should exceed $9,287.3 in year 2007 for a

[33] Due to the limited processing capacity in Canada and the focus on younger (less than 30 months old) cattle of large processing operations, the collective herd size in Alberta has grown since 2004 (in Figure 6.5), with the ranks of older cattle swelling.

herd expansion to occur. Interpretation of this expansion threshold revealed that unless the calf price rises above $154.3 per cwt. keeping all other variables the same, expanding the herd by 10 cows would not be economically profitable in 2007. This price level implied that expanding the herd size would not be feasible in 2006-2007 without a full recovery of Alberta cattle industry (e.g. calf price bounces back to 2000-2001 level). However, an expansion would only be triggered by an economic value of $9,287.3 when the cost of the cows was less than $7,447.8 ($745 per head). Thus, the spread between the two assets should be greater than $9,287.3 - $7,447.8 = $1,839 along the border at the bottom. The intuition is that with the economic value of $9,287.3 in an uncertain environment, the $1,839 is the spread threshold in 2007 to trigger the herd expansion and to cover the value of waiting until some later period. However, when the cost of the cows rises above $7,447.8, the economic value of cows must rise along the bold borderline to a value higher than $9,287.3 to trigger a herd expansion. For example, the expansion thresholds at point A would be $12,606.42 for the economic value of cows while $9,436.55 ($944 per head) was the cost of acquiring the cows. Following the same logic, a set of expansion thresholds can be drawn from the bold borderline in Figure 6.6 to provide information on future investment policy. It is important to recognize that the combinations of asset values for expansion with high cumulative probabilities which are more likely to occur in 2007 are indicated by the dark shading in Figure 6.6. Thresholds in the light shading area may not be as informative due to the low cumulative probabilities.

The thresholds of herd contraction in 2007 can be drawn from the shaded area in Figure 6.7. All the possible paired asset values for a contraction of 10 cows to be executed in 2007 without waiting any further were plotted in the area. The sales revenue in the contraction thresholds should be at least $6,773.3 while the forgone economic value of cows is $4,893.2. The sales revenue and forgone economic values of cows translate into feeder cow price of $53.3 per cwt. and calf price of $113.6 per cwt., keeping other prices the same in 2007. This implied the forgone economic values of cows lower than $4,893.23 or calf price lower than $113.6 may have resulted in herd contraction in 2006 already without waiting till year 2007. The spread threshold to trigger the herd contraction in 2007 and to cover the value of waiting

beyond 2007 was \$6,773.3 - \$4,893.2 = \$1,880. For forgone economic values of cows higher than \$4893.2, the corresponding sales revenue of cows associated with contraction thresholds can be drawn along the bold borderline in Figure 6.7 to provide information on future investment policy design. The high sales revenue of cows associated with the contraction thresholds (at least \$6,773.3) would probably suggest that the cows in the herd should be resold to other producers as bred cows rather than as cows for slaughter. Only when breeding cows are sold as bred cows to other breeding herds, can the sales revenue of the cows be high enough to trigger a herd contraction in 2007 and to cover the option value of waiting.

In Figure 6.8, the shaded area was representative of the possible asset value combinations in year 2008 for undertaking a herd expansion of 10 cows. The expansion thresholds can be drawn accordingly. The economic value of 10 cows should exceed \$19,796.6 in 2008 for a herd expansion to occur. However, keeping other variables the same, it is somewhat difficult to interpret this expansion threshold because calf price would have to be as high as \$210 per cwt. to achieve an economic value of cows of \$19,796.6. This extremely high calf price resulted from the expansion thresholds provided an indication that thresholds extracted from the early exercised nodes in the spread option model may not be as informative and useful to assist with investment policy design over a longer term. Due to the lognormality assumptions of the economic value of cows and cost of bred heifers in conjunction with the geometric Brownian motion, the two asset values may deviate away from their present values over the long term. Therefore, thresholds extracted from the early exercised nodes in the spread option model beyond two years ahead may appear unrealistic from a practical point of view.

Similar to Figure 6.8, the shaded area in Figure 6.9 was representative of the possible asset value combinations in 2008 for undertaking a herd contraction of 10 cows. The sales revenue of 10 cows should exceed \$38,716.6 in year 3 for a herd expansion to occur. Keeping all other variables the same, the \$38,716.6 sales revenue translates into a feeder cow price of \$304.7 per cwt. This threshold for herd contraction in 2008 seemed extremely high considering cow prices have never been so high. Since thresholds analyses beyond 2 years in Figure 6.8 and 6.9 did not

provide useful information to the long-term investment policy design of the underlying operation, it was determined the expansion/contraction thresholds beyond 2 years would not be presented for the other scenarios.

Scenario 2 – Best case (year 2000)

In this scenario, it was assumed the average prices in 2000 were used as price estimates to calculate the economic value of cows using Equations 5.1 and 5.2. The NPV results for expansions and contractions were calculated and listed in Table 6.8.

Both NPV results in herd expansions were associated with positive values ($818 and $725) and suggested it would have been profitable for cow/calf producers to expand herd size in 2000. This occurred because of the increase in revenue caused by high cattle prices and modest production costs represented by hay price. For herd contractions, the NPV for contraction with 10 cows was -$3,893 whereas the NPV for 20 cows was -$5,874. Hence, regardless of the uncertainty associated with future market conditions, the positive NPV suggested that expansion of herd size by 10 to 20 cows in 2000 would enhance herd profitability. Looking at Figure 6.5, the actual increase of the cow population in 2002 was consistent with the decision to expand herd size under the NPV framework.

The real option results inherent in the expansion/contraction decisions were listed in Table 6.9. The option values associated with the decision to expand were larger than those with the decision to contract. As the time to maturity increased, the difference between the option values associated with expansion and contraction became smaller. This implied that making decisions regarding changing herd size in the long term can not be simply based on current market conditions. In spite of the favorable prevailing cattle prices in 2000, herd expansion and contraction in the long term warrant an equal amount of caution to account for market uncertainty.

The option values were implemented into the decision making regarding herd expansion/contraction. Contracting the herd size would still not be in the best interests of the producers under the year 2000 prices. As for herd expansions, the decision was to expand the herd size by 10 to 20 cows under the NPV framework. However, the NPV results of herd expansions ($818 and $725) were not sufficient to

cover the forgone option values of waiting in 1 year ($1,784 and $2,424). The expansion decision was altered by the flexibility to postpone the decision and the decision thus became waiting for at least 1 year. The decision rule of herd contraction after taking the $1,784 and $2,424 option to wait value into account suggested that the calf price should be as high as $154 per cwt., keeping all other variables the same, for expansion of 10-20 cows to be undertaken immediately in 2000 without waiting. Based on Figure 6.5, the decision to wait with regard to herd expansion in 2000 under the real options framework did not match the observed increase in cow population in 2000. However, given the continuously evolving market conditions in the succeeding years, the loss in an unforeseeable event such as the BSE in 2003 would have been alleviated, had the herd not expanded in 2000.

Figures 6.10-6.11 provided insights regarding investment policies for the underlying operation such as under what circumstances should herd be expanded or contracted in year 2002 which is two years after 2000. Based on Figure 6.10, the shaded area was representative of the possible asset value combinations in year 2 for an expansion of 10 cows to be undertaken. Generally, the economic value of 10 cows should exceed $30,747 in 2002 for a herd expansion to occur. This would require a calf price over $200 per cwt. Although this calf price did not appear to be reasonable, an expansion threshold this high in 2002 would probably suggest that most relevant expansion thresholds within a reasonable range were generated a year earlier in 2001. Therefore, it can be inferred herd expansions would have been executed in 2001 given two consecutive years (e.g. year 2000 and 2001) with favorable market conditions.

Based on Figure 6.11, the sales revenue of 10 cows $40,719 ($4,072 per breeding cow) associated with the contraction thresholds in 2002 seemed unrealistic. However, the extremely high threshold results may suggest that a herd contraction would be very unlikely in the next 1-2 years after a single year with high cattle prices (such as in year 2000).

Scenario 3 – Pre-BSE (2002 - May 2003)

In this scenario, average prices for the period of 2002 to May 2003 were used as price estimates to calculate the economic value of cows using Equations 5.1 and 5.2. The NPV of herd expansion or contraction calculated from the economic value of cows were listed in Table 6.10.

Both NPV results in herd expansions were associated with negative values (-$6,436 and -$13,555) and were unattractive for cow/calf producers to expand herd size. The negative NPV results were caused by the decrease in cattle prices and the increase in hay price. Comparing with scenario 2, the calf price, on average, was 12.9% lower while the hay price was 65.7% higher. The higher hay price occurred because drought conditions were prevailing in 2001 and 2002 and severely reduced the hay production in Alberta (AAFRD, 2002). For herd contraction, both NPV results were associated with positive values ($339 and $1,700). Hence, the positive NPVs suggested contracting herd size by 10 to 20 cows during 2002 to early 2003.

The real option values inherent in the expansion/contraction decisions under Scenario 3 were presented in Table 6.11. Due to the largely negative NPVs associated with herd expansions, expanding the herd size would not be feasible in 2002 and 2003 under the real options framework. As for the herd contractions, the positive NPV must exceed the estimates of the corresponding option values of waiting for herd contractions before the decisions are made, taking the uncertainty associated with future market conditions into consideration. Since the NPV results for herd contraction of 10 and 20 cows ($339 and $1,700) were less than the option to wait values in 1 year ($1,249.5 and $2,793.6), the contraction decision was altered by the flexibility to postpone the decision. Interpretation of the decision rule of herd contraction after taking the $1,249.5 option to wait value into account revealed that unless the calf price drops to $125.67 per cwt. or feeder cow price goes up to $66.9 per cwt. during 2002 to May 2003, keeping all other variables the same, herd contraction of 10 cows should be postponed. The decision thus became to wait for at least 1 year before contracting the herd size when there may be more market information.

The area of the paired asset threshold values associated with the investment policies for expansion and contraction of 10 cows in two years (2004-2005) were

graphically portrayed in Figures 6.12-6.13. Based on Figure 6.12, the shaded area was representative of the possible asset value combinations in 2004-2005 for undertaking a herd expansion of 10 cows. The economic value of 10 cows should exceed $10,458 in 2004-2005 for a herd expansion to occur while the cost of cows was below $8,465 ($846.5 per head). Interpretation of this expansion threshold revealed that unless the calf price rises to $161.8 per cwt. in 2005, keeping all other variables the same, expanding the herd by 10 cows would not be in the best interests of cow/calf producers.

In Figure 6.13, the shaded area was representative of the possible asset value combinations in year 2004-2005 for a herd contraction of 10 cows. The extremely high sales revenue of 10 cows $24,699 ($2,470 per breeding cow) associated with the contraction thresholds in 2004-2005 seemed unrealistic to be implemented into the investment policy. However, it can be inferred that most herd contractions would have been triggered in 2003 in cases where lower thresholds for contraction were met. This inference is consistent with the observed entire cow herd contraction in Alberta in 2003.

Scenario 4 – Post-BSE (June 2003 - April 2004)

In this scenario, average prices for the period of June 2003 to April 2004 after the discovery of the first BSE case in northern Alberta were used as price estimates to calculate the economic value of cows using Equations 5.1 and 5.2. The NPV of herd expansion or contraction calculated from the economic value of cows were listed in Table 6.12.

The NPV results of herd expansion were largely negative (-$7,468 and -$15,501) and suggested herd expansions during the period of June 2003 to April 2004 would worsen the situation for cow/calf producers. The negative NPVs were results of the low cattle prices caused by the discovery of BSE and the closure of export markets for that matter. Comparing with scenario 2, the calf price and cull cow price, on average, were 29% and 64% lower. This had a large negative impact on cow/calf producers' cash inflows and caused a negative NPV. For herd contractions, although the feeder cow price had dropped by over 44% compared with year 2000, the NPV

results for herd contractions were associated with positive values ($1,499 and $3,574) and were attractive to producers. Therefore, regardless of the uncertainty associated with future market conditions, the positive NPVs suggested that cow herd should be contracted by 10-20 cows immediately.

The next set of results in Table 6.13 concern the real option values inherent in the expansion/contraction decisions. The option values of waiting associated with the herd expansion decision during June 2003 to April 2004 were close to zero due to the large negative spread between the low economic value of cows and the cost of bred heifers. Therefore, the decision rules for herd expansion under the real options framework were the same as those under the NPV framework. Expanding the herd size would not be feasible due to the largely negative NPVs associated with herd expansions during 2003 and 2004.

The positive NPVs associated with herd contraction of 10-20 cows indicated contracting the herd size immediately would reduce the shortage of cash flows of the cow/calf operation. However, when real option value is considered, the herd is contracted only if the expected NPV is sufficient to cover the forgone option value of waiting. Since the NPV results for herd contraction of 20 cows ($3,574) was equal to the option to wait value in 1 year ($3,574), the herd contraction decision should be made immediately in 2003 under the real options framework without waiting for more market information until 2004-2005. Under the post-BSE market conditions in 2003-2004, a clear contraction decision of 20 cows was indicated by the real option results. This contraction decision under the real options framework was consistent with the actual decline of the cow population on Alberta farms in 2003 (Figure 6.5) after the BSE outbreak[34].

Since there was no option value associated with the decision to expand the herd size under this scenario, only the area of the paired asset thresholds associated with the investment policy for herd contraction in year 2006 was graphically portrayed in Figure 6.14. The sales revenue of 10 cows should exceed $10,204.7 in year 2006 for a herd contraction to occur given the forgone economic value of 10

[34] In reality, the contraction of cow population on Alberta farms in 2003 was restricted by the limited processing capacity in Canada and the closure of export markets for Canadian live cattle after the BSE outbreak.

cows went up to $8,199. Thus, the spread threshold to trigger the herd contraction and to cover the value of waiting beyond 2006 was $10,204.7 - $8,199 = $2,005.7 along the border at the bottom. The interpretation of this sales revenue and forgone economic revealed that keeping all other variables the same, unless the feeder cow price goes up to $80.3 per cwt., provided calf price bounces back to $145.91 per cwt., contracting the herd by 10 cows would not be economically profitable in 2006. Corresponding sales revenues associated with contraction thresholds for higher forgone economic value of cows can be obtained along the bold borderline in Figure 6.14. The high contraction thresholds indicated that providing the cattle industry starts to recover, it would probably be economically feasible to sell cows as bred animals to other producers for herd contractions in 2006.

The above discussed decision criterions with regard to changing herd size under the NPV and the real options frameworks as well as the implications for investment policy to follow under different scenarios were summarized in Table 6.14 and were compared to the actual historical changes of the entire cow population in Alberta. This provided performance implications of the real options model and an indication of the influence real options may have on the decision to change herd size.

Sensitivity Analysis

From the real option values presented in the above scenario analyses, it can be concluded that the option values are sensitive to changes in the values of the two underlying assets and time to maturity of the opportunity to vary herd size. On the other hand, whether different volatilities of asset returns can cause large changes in option values is examined as following.

A set of sensitivity analysis was conducted utilizing the base case scenario to evaluate the impact of the volatility on option results with 20 animals (Figure 6.15 and 6.16). The uncertainty is measured by the volatility of the returns from the economic value of cows in herd expansion/contraction. Following Davis (2002), since there is a positive relationship between the volatility of the return of the cow/calf operation and the risk adjusted discount rate estimated by the principle of the Capital Market Line (CML) model, the discount rate is changing simultaneously with the

volatility. Therefore, the economic values of cows which have been discounted should be varying with the volatility in the calculation of the option value as well, holding all other variables constant. In order to capture this relationship between the volatility and the economic value of cows discounted by the risk adjust discount rate, it is assumed the changes in volatility of the returns from the economic value of 20 cows represent the changes in volatility of the return of the cow/calf operation. Therefore the discount rate and the economic value of cows change in concert with the volatility of the returns from the economic value of cows.

The volatility was varied from 10% to 80% and the corresponding values of the option to wait were observed. Figures 6.15 and 6.16 show that the option values for both expansion and contraction were increasing as the volatility of the return from changing herd size increased. Following Davis (2002), both the increase in option values as a result of increasing volatilities and the effect of decreasing economic value of cows caused by increments in discount rate estimated from the CML model are included in option value calculations at different volatilities. However, the total effect shows the option values were sensitive to volatilities.

6.1.3 Evaluation of the Real Option Model in the Cow/Calf Sector

Based on the above findings, there exist significant real option values inherent in the decisions to change herd size which involve apparent uncertainty and irreversible costs. The real option values have important implications for not only the investment decisions today but also the investment policy to follow during a specified period of time. More specifically, implementing real option values into the decision making regarding herd expansion/contraction has altered most of the herd expansion/contraction decisions made under a conventional NPV framework. Waiting for more market evidences has been often suggested by the real option model as opposed to the expansion/contraction decisions made under the NPV framework. The reason may be that, under uncertainty and irreversibility, the NPV which leads to an instant investment or a permanent disinvestment decision may be found not sufficient to compensate the forgone flexibility represented by the option to wait values. However, under Scenario 4, the real option model clearly indicated that the herd

should be contracted by 20 cows immediately in 2003. This contraction decision was consistent with the decision made under the NPV framework.

Innovative insights regarding investment policies for the underlying cow/calf operation such as under what circumstances should cow herd be expanded or contracted in a future time period within two years are provided by analyzing the early exercised nodes in the three-dimensional spread option model. Implications for future investment policy design for individual cow/calf operations such as those listed in Table 6.14 can be drawn from the threshold values associated with the early exercised nodes. One particularly interesting result is that the option to wait values may provide a possible explanation for the non-decreasing herd size one year after the BSE.

Limitations of the Real Options Model in the Cow/Calf Operation

The underlying asset values, volatility of the asset returns and time to maturity of the opportunity to vary herd size all affect the real option values. Since the calculations of the underlying economic value of cows rely on simplified assumptions regarding future prices, using a different set of economic values of cows generated by cattle price forecasting models may result in different option values.

Due to the lognormality assumptions of the economic value of cows and cost of bred heifers in conjunction with the geometric Brownian motion, thresholds of the economic value of cows and cost of bred heifers/sales revenue of cows extracted from the early exercised nodes in the spread option model, especially when the time to maturity goes beyond 2 years, may appear unrealistic when implemented into future investment policies. For example, the extremely high thresholds for herd expansions/contractions in Figures 6.8-6.9, Figure 6.11 and Figure 6.13 were very difficult to interpret from a practical point of view. However, changing the lognormality assumption may result in fundamental changes in option valuation models. It is important to recognize that judgments are required to interpret the thresholds and draw useful implications from the three-dimensional binomial model for future investment policy.

Looking at Table 6.14, when compared to the historical changes in the entire cow population on Alberta farms, decisions made under the real options framework did not follow the reality more closely than the decisions made under the NPV framework. Although performance implications of the real option model in the cow/calf operation require more empirical evidence, the real option model did not outperform the NPV in explaining the changes of the collective herd size in Alberta under the scenarios discussed in this thesis. In addition, calculating the option values using different time steps can affect the value of the options and therefore the influence on decision making.

In conclusion, the real options approach has the potential to be a capital budgeting tool for aiding long-term investment decisions in changing herd size in the cow/calf operation. However, caution should be suggested in embodying the model assumptions such as the lognormality of the assets' distributions and interpreting the option model results such as the threshold values extracted from the early exercised nodes. The real options model yet may not outperform the conventional capital budgeting method such as the NPV in explaining the historical changes of the herd size. Nevertheless, innovative insights extracted from the real option model regarding future investment policies have not been provided by other traditional capital budgeting models before.

6.2 Real Option Results in the Feedlot Operation

Based on the model parameters for spread options in the feedlot operation in Table 5.3, the value of the option to wait inherent in the decision to place a pen of feeder cattle in feedlot was calculated to be $0.2 for an entire pen of cattle. The low real option value was largely attributed to the negative net profit ($-31,680) which was the spread between the sales revenue of fed cattle and the purchase cost of the feeder cattle less the production costs reported in Table 5.3.

Compared with the large negative expected net profit of finishing a pen of feeder cattle in June 2005, the $0.2 option to wait value obtained from the spread call option model is sufficiently small to be ignored. It implies that the option to wait value will not be a serious consideration in making the decision of placing feeder

cattle in feedlots in June 2005. Thus, the decision based on the expected net profit will be not feeding the pen of feeder cattle under the market conditions in June 2005.

To examine the sensitivity of option to wait values to changes in the two underlying asset prices, alternative prices of fed cattle and feeder cattle were used in the spread call option model. The annual average 8-9 cwt. feeder cattle price during 2000- 2003 ranged from $98 per cwt. to $123 per cwt. while the annual average fed cattle price during 2000- April 2004 ranged from $85 per cwt. to $103 per cwt. These ranges of feeder cattle and fed cattle prices were listed in Table 6.15 with $1 per cwt. increment. Corresponding option to wait values were calculated using each of the fed and feeder cattle price combinations as values of underlying assets and presented in Table 6.15. The expected net profits of finishing a pen under the price combinations were calculated using the sales revenue of fed cattle less the purchase cost of feeder cattle and the production costs in Table 5.3. The expected net profits as determinants for making the feeder cattle placement decision were listed in Table 6.16. As most of the expected net profits are negative, cattle feeders may be considered irrational when they still place cattle on feed[35].

Looking at Table 6.15, the option value increases with the increase in fed cattle price and decreases as the feeder cattle price raises. The values of the option to wait are sensitive to changes in the spread between the fed cattle price and the feeder cattle price. As the spread between the fed cattle price and the feeder cattle price decreases, the option value drops quickly. For example, the $6,080 option to wait value for finishing a pen of feeder cattle with a zero price spread between $102 per cwt. fed cattle price and $102 per cwt. feeder cattle price drops to $74 per pen with a -$15 per cwt. spread between $94 per cwt. fed cattle price and $109 per cwt. feeder cattle price. The highest option value $6,080 per pen occurs with the best pricing situation for cattle feeders where fed cattle prices equals feeder cattle price at $102 per cwt.

Based on Table 6.16, feeding a pen of feeder cattle was mostly associated with large negative net profits and was unattractive to feedlot producers. Positive net

[35] Kastens and Schroeder (1994) concluded one explanation for this irrational behavior of cattle feeders was that fed cattle prices were expected to increase over the feeding period.

profits were possibly resulted only when fed cattle prices were higher than $100 per cwt. while feeder cattle prices were below $105 per cwt. This occurred because of the high production costs of finishing a single pen reported in Table 5.3. Therefore, the decision associated with feeder cattle placement under the high production costs would be not to feed the pen of feeder cattle. Under the real options framework, when the option to wait values are added to the net profits, most of the net profits are still associated with negative values and the decision of not feeding the pen does not change. However, when fed cattle prices were above $99 per cwt. and feeder cattle prices were below $106 per cwt., the option to wait values may alter the decision of not feeding the pen, and suggest that feedlot producers should wait for better pricing opportunities to bring in the feeder cattle. On the other hand, the positive net profits were not sufficient to cover the option to wait values under favorable market conditions. For example, the highest option value $6,080 per pen was greater then the positive profit of $4,570 from feeding the pen of feeder cattle when fed cattle price and feeder cattle price were both $102 per cwt. Thus, the decision of feeding the cattle under such pricing situation was altered by the option to wait value. No feeder cattle should be placed in feedlots immediately.

Generally, when fed cattle price goes below $99 per cwt. while the feeder cattle price rises above $106 per cwt., the option to wait value does not have any impact on the decision of placing feeder cattle on feed or not. Historically speaking, fed and feeder cattle prices fell into this range the majority of time during 2000-2003. Therefore, under the prevailing market prices, the option to wait value may not have any significant impact on feedlot producers' decision of placing feeder cattle in feedlots.

Sensitivity Analysis

Aside from the price spread which largely influences the option to wait value, sensitivity analysis on other model parameters can be employed to investigate the possible causes of the comparatively low option values inherent in the feeder placement decision in the feedlot operation. Each analysis was performed by varying one of the model parameters and calculating the corresponding option values while

keeping other model parameters the same. To determine the impact of the production costs in finishing a pen of feeder cattle on the option values, the production costs were reduced by a percentage from 10% to 50% and the corresponding option values were observed, holding all other model parameters constant. Table 6.17 presented the percentage change in option values with respect to the reductions in production costs. The results indicated that the option to wait value in the feedlot operation was very sensitive to the production costs. The option values were increasing rapidly as the percentage of production cost reduction increased. The largest percentage change in option value was 87% when a 10 percent cost reduction occurred. However, the size of the percentage increase in option value decreases as the percentage reduction in production costs increases. The highest option value was $674 per pen as a result of a 50% reduction of production costs.

Besides the variable production cost, the feedlot operations are characterized by the relatively short time frame and the high correlation between fed cattle and feeder cattle prices. The time frame and the correlation between the returns of fed cattle price and feeder cattle price were examined for their impacts on the spread option value in Figures 6.18-6.19.

In Figure 6.18, the time to maturity of the spread option was adjusted for a range from 0.25 year to 2.5 years with 0.25 year increment while holding other variables constant. As expected, with longer time to maturity, the spread option value becomes larger in value. The increments of the option value were increasingly large which means the impact of the time to maturity on the spread option value was higher in longer time frames than in shorter time frames. The option value with a 2.5 year life could go as high as $500 per pen. However, long time frames are not realistic in feedlot operations given the nature of cattle feeding. The result implies that the short decision window in the feedlot operation may be one of the explanations of the low spread call option value in the feedlot operation.

Figure 6.19 depicted the relationship between the correlation of the underlying assets and the option value. All things being equal, as the correlation increases from -0.20 to 0.80, the spread option value drops very quickly. More specifically, a $550 spread option value with a -0.20 correlation was largely eroded once the correlation

rises above zero. This is an important result because it may provide another explanation of the low spread call option value in the feedlot operation. When the underlying assets in the spread option show high positive correlation in returns, the option to wait that depends on the spread is inversely affected. As the positive correlation between the returns of the two underlying assets increases, it is more likely that expected values of the two assets over the succeeding periods move in the same direction and narrow the spread in between. Therefore, less value is created for the payoff function and the underlying spread call option value.

6.2.1 Evaluation of the Real Option Model in the Feedlot Sector

The real option value arising from the decision to place a pen of feeder cattle in the feedlot, which, in this case, appears as an option to wait, is found to be insignificant in most cases. The reasons for the insignificant option value are mainly the negative price spread between fed cattle and feeder cattle prices, high production costs, short time to maturity and the high correlation between feeder cattle and fed cattle prices.

In option pricing theory, limited time to maturity and the high correlation between asset returns in the spread payoff functions jointly decrease the spread call option value. Due to these characteristics inherent in the short-term decision timeframe in the feedlot operation, the option to wait in the feeder cattle placement decision may not be as valuable as the one in the long-term investments in the cow/calf sector. A more straightforward approach may be using a simple budget to evaluate the decisions of feeding a pen of feeder versus leaving the feedlot empty over one turnover of cattle finishing. The actual net profit from the budget which depends on the cash market prices may be a determinant for making such decisions.

Other limitations of the spread option model in the feedlot operation may be revealed by the model assumptions. It is assumed that the total production cost including feed cost and yardage cost is used as a total fixed cost in the spread option model in the feedlot operation. In the real-world cattle feeding operations, however, the feed cost exhibits large variability from year to year due to variations in feed grain prices such as barley price. Although the variability can be reduced by signing barley

futures contract, the feed cost is still subject to basis risk. Therefore, the assumption of a fixed production cost may not be appropriate. The correlation between the returns of fed cattle price and feeder cattle price is incorporated into the spread option model. However, historically there was correlation between the returns of feed grain price and feeder cattle price as well[36]. This correlation is the result of complicate supply and demand relationships. Failure to include the correlation of returns between feed grain price and feeder cattle price may also result in incorrect real option results. Taking the stochastic feed cost and the correlation between the returns of barley price and feeder cattle price into account, there exist multiple correlated risky assets in the real option payoffs within the feedlot operation. Therefore, the three-dimensional spread option model may not the best model to evaluate the identified decision in the feedlot operation.

6.3 Chapter Summary

This chapter discussed the results of the real option values associated with identified decisions in the cow/calf operation and the feedlot operation. Significant real option values were found in the herd size expansion/contraction decisions in the cow/calf operation using the estimated model parameters. The option values contribute to a better understanding of what are the decision rules to vary herd size to help offset risk and uncertainty. Implications for future investment policy regarding the timing and thresholds of herd expansion/contraction can be drawn from the spread option model, although the extracted thresholds require caution and judgments to interpret.

The spread call option analysis in the feedlot sector produced insignificant option values, deeming the option values not numerically large enough to be considered with the net profits of the cattle feeding operation. The option value in the feedlot operation is largely reduced by the negative price spread between the fed and feeder cattle prices, high production costs, short time period and the high correlation between fed and feeder cattle prices. Therefore, a simple budget maybe more effective in assisting with cattle placement decisions in the feedlot.

[36] The correlation of historical returns of barley price and feeder cattle price during the period of 1977 to 2004 is calculated to be 0.248.

6.1 Tables for Chapter 6

Table 6.1 Profit/Loss Results for Expansion of 10 Cows in the Cow/Calf Operation

Months of Cow herd Expansion	Historical Profit/Loss (10 cow expansion), by Year																	
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Jan	2566	3740	4363	(808)	(2516)	(1982)	410	112	(205)	780	1659	798	(1282)	(474)	343	(766)	589	(1597)
Feb	2679	4088	4526	(1536)	(2156)	(1404)	509	(169)	60	939	1688	528	(1098)	266	463	(582)	832	(859)
Mar	3071	4288	4169	(2308)	(1238)	(1210)	537	(171)	135	789	1827	385	(558)	877	1274	(302)	417	(1201)
Apr	2944	4256	3353	(2311)	(792)	(1329)	290	(331)	212	958	2243	669	198	1445	1582	(274)	391	(1283)
May	2829	4256	2606	(2061)	(453)	(903)	(34)	(411)	589	878	2221	115	988	1482	1168	(203)	348	
Jun	3274	4396	2281	(1744)	(135)	(552)	(169)	(340)	544	833	2060	28	917	1477	817	(367)	283	
Jul	3251	4290	2054	(1554)	(800)	(767)	(250)	(282)	477	1454	1722	74	467	1393	898	(136)	417	
Aug	3069	3998	1478	(1430)	(1283)	(647)	(580)	(315)	407	1761	1588	(15)	845	1479	902	267	693	
Sep	3107	4071	1310	(1818)	(1648)	(605)	(510)	275	550	1517	2018	(695)	561	1033	484	(590)	(259)	
Oct	3064	3729	353	(1578)	(2005)	(308)	(235)	164	156	1264	605	(1028)	197	214	(77)	(621)	(1070)	
Nov	2679	3120	570	(1435)	(2370)	(435)	(591)	(388)	118	1100	732	(1145)	(452)	(167)	(1091)	(664)	(1315)	
Dec	2980	3527	1245	(2113)	(2138)	(318)	(185)	(345)	313	1421	1094	(919)	(598)	(147)	(580)	7	(1497)	

Notes: Numbers in parentheses are losses associated with herd expansions. For example, an expansion of 10 cows in January 1979 would have resulted in a loss of $808 whereas an expansion of the same size in January 1976 would have resulted in a profit of $2,566 over the life of the cows.

Table 6.2 Profit/Loss Results for Expansion of 20 Cows in the Cow/Calf Operation

Months of Cow herd Expansion	Historical Profit/Loss (20 cow expansion), by Year																	
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Jan	4297	7339	8531	(1992)	(5242)	(4005)	470	(431)	(1107)	1027	2745	1023	(3387)	(2084)	(327)	(1715)	1148	(3276)
Feb	4569	8102	8716	(3489)	(4577)	(2894)	607	(959)	(502)	1377	2720	489	(2958)	(567)	(54)	(1202)	1641	(1781)
Mar	5386	8449	7810	(5063)	(2751)	(2472)	692	(911)	(250)	1160	3068	203	(1962)	596	1528	(788)	799	(2475)
Apr	5188	8361	6140	(4979)	(1809)	(2657)	219	(1159)	(53)	1504	3854	713	(515)	1691	2195	(713)	723	(2702)
May	4974	8256	4602	(4423)	(1061)	(1856)	(509)	(1217)	687	1322	3729	(411)	1013	1817	1482	(494)	551	
Jun	5894	8497	3928	(3810)	(420)	(1213)	(750)	(1065)	557	1185	3299	(653)	870	1935	877	(779)	307	
Jul	5825	8210	3541	(3382)	(1661)	(1661)	(926)	(1048)	393	2380	2719	(514)	(65)	1793	1109	(381)	470	
Aug	5567	7687	2549	(3051)	(2553)	(1511)	(1702)	(1193)	312	3090	2560	(643)	658	1875	1137	420	1016	
Sep	5709	7909	2271	(3794)	(3326)	(1463)	(1604)	19	559	2612	3344	(2052)	(38)	1017	307	(1212)	(746)	
Oct	5779	7249	458	(3358)	(4036)	(934)	(1035)	(265)	(281)	2023	490	(2816)	(733)	(522)	(634)	(1231)	(2358)	
Nov	5074	6104	917	(3112)	(4793)	(1190)	(1770)	(1349)	(353)	1638	789	(3046)	(1972)	(1234)	(2560)	(1330)	(2852)	
Dec	5672	6935	2097	(4538)	(4356)	(891)	(897)	(1277)	55	2298	1522	(2626)	(2324)	(1267)	(1488)	48	(3163)	

Notes: Numbers in parentheses are losses associated with herd expansions. For example, an expansion of 20 cows in January 1979 would have resulted in a loss of $1,992 whereas an expansion of the same size in January 1976 would have resulted in a profit of $4,297 over the life of the cows.

Table 6.3 Profit/Loss Results for Contraction of 10 Cows in the Cow/Calf Operation

Months of Cow herd Contraction	Historical Profit/Loss (10 cow contraction), by Year															
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	(1961)	(4278)	(6379)	(1405)	1471	1384	(558)	(1627)	(921)	(1830)	(3014)	(3300)	(584)	(751)	(907)	(1040)
Feb	2518	(4679)	(6387)	(295)	1006	946	(968)	(1073)	(1055)	(1701)	(3053)	(3007)	(1664)	(741)	(352)	(849)
Mar	4915	(4910)	(5817)	621	225	156	(1172)	(820)	(978)	(1526)	(2891)	(2158)	(928)	(506)	(1183)	(2057)
Apr	2851	(5151)	(4488)	543	(200)	621	(865)	(475)	(810)	(1227)	(3054)	(2647)	(1987)	(2305)	(2620)	(2614)
May	3558	(5365)	(3819)	875	(477)	304	(746)	(282)	(1152)	(1338)	(2870)	(2021)	(404)	(2331)	(2779)	(2398)
Jun	5246	(5091)	(4039)	960	(150)	431	(128)	(423)	(888)	(1248)	(3287)	(2211)	(2165)	(3307)	(2471)	(1770)
Jul	2316	(4974)	(3745)	709	(605)	556	(215)	(205)	(781)	(2263)	(2666)	(2292)	(1646)	(1798)	(1290)	(1675)
Aug	4130	(5073)	(3622)	178	560	878	40	(174)	(973)	(2722)	(2885)	(1186)	(2169)	(1826)	(1262)	(1527)
Sep	2291	(5528)	(3449)	717	1406	679	166	(840)	(1499)	(1652)	(3145)	(1031)	(1388)	(1842)	(1160)	(1577)
Oct	2691	(5398)	(2250)	193	1618	(38)	(421)	(1071)	(1255)	(2485)	(2747)	(1132)	(1749)	(1355)	(708)	(1453)
Nov	4136	(4760)	(2003)	65	2329	298	(661)	(441)	(1778)	(2672)	(2984)	(1320)	(1513)	(876)	(1298)	(1014)
Dec	3510	(5215)	(2283)	441	1409	(750)	(1026)	(792)	(1296)	(2361)	(3072)	(1566)	(1563)	(1539)	(1553)	(1609)

(Table 6.3 continued on the next page.)

Notes: Numbers in parentheses were losses associated with herd contractions. For example, a contraction of 10 cows in January 1977 would have resulted in a loss of $4,278 whereas a contraction of the same size in March 1979 would have resulted in a profit of $621 over the life of the cows.

(Table 6.3 continued.)

Months of Cow herd Con-traction	Historical Profit/Loss (10 cow contraction), by Year					
	1992	1993	1994	1995	1996	1997
Jan	(1856)	(371)	2330	2334	(1607)	(3876)
Feb	(1578)	76	1761	2054	(2527)	(4040)
Mar	(2544)	(304)	1931	1831	(2572)	(3169)
Apr	(2294)	(498)	2717	1027	(3018)	(2463)
May	(2166)	26	2962	514	(3332)	
Jun	(1949)	616	2334	543	(3494)	
Jul	(1920)	580	2287	(165)	(3471)	
Aug	(2561)	1089	1979	(655)	(3115)	
Sep	(2074)	1769	2569	(424)	(3053)	
Oct	(719)	2290	2618	(100)	(2451)	
Nov	(290)	2571	2675	(504)	(2771)	
Dec	(177)	2490	1827	(457)	(3481)	

Table 6.4 Profit/Loss Results for Contraction of 20 Cows in the Cow/Calf Operation

Months of Cow herd Con-traction	Historical Profit/Loss (20 cow contraction), by Year															
	1976	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Jan	(2362)	(7315)	(11797)	(2167)	3682	3697	(223)	(2272)	(582)	(2108)	(4705)	(5479)	61	(118)	(230)	(715)
Feb	2518	(8168)	(11778)	74	2913	2794	(990)	(1174)	(828)	(1907)	(4797)	(4845)	(2066)	(84)	894	(439)
Mar	4915	(8677)	(10659)	2029	1362	1178	(1421)	(676)	(675)	(1583)	(4529)	(3149)	(565)	602	(771)	(2730)
Apr	2851	(9180)	(8003)	1854	514	2069	(831)	(19)	(302)	(1021)	(4821)	(4037)	(2563)	(2909)	(3627)	(3769)
May	3558	(9632)	(6611)	2552	(86)	1364	(505)	378	(937)	(1291)	(4504)	(2684)	680	(3028)	(3964)	(3434)
Jun	5246	(9108)	(7086)	2797	605	1705	691	145	(401)	(1149)	(5214)	(3058)	(2810)	(5018)	(3391)	(2287)
Jul	2316	(8836)	(6516)	2252	(371)	1924	494	637	(176)	(3138)	(3991)	(3272)	(1826)	(2020)	(984)	(2065)
Aug	4130	(9080)	(6430)	1147	1917	2586	1011	746	(516)	(4094)	(4516)	(1137)	(2846)	(1969)	(855)	(1765)
Sep	2291	(9980)	(6197)	2144	3639	2204	1281	(526)	(1577)	(1960)	(5055)	(805)	(1280)	(2074)	(725)	(1963)
Oct	2691	(9710)	(3921)	1188	3980	874	120	(993)	(1035)	(3684)	(4318)	(1007)	(2072)	(1152)	(5)	(1863)
Nov	4136	(8547)	(3367)	831	5498	1436	(373)	239	(2182)	(3970)	(4871)	(1369)	(1654)	(323)	(1190)	(1058)
Dec	3510	(9427)	(3885)	1669	3674	(637)	(1141)	(504)	(1113)	(3371)	(4965)	(1853)	(1750)	(1561)	(1714)	(2187)

(Table 6.4 continued on the next page.)

Notes: Numbers in parentheses are losses associated with herd contractions. For example, a contraction of 20 cows in January 1977 would have resulted in a loss of $7,315 whereas a contraction of the same size in March 1979 would have resulted in a profit of $2,029 over the life of the cows.

(Table 6.4 continued.)

Months of Cow herd Con-traction	Historical Profit/Loss (20 cow contraction), by Year					
	1992	**1993**	**1994**	**1995**	**1996**	**1997**
Jan	(2618)	(6)	5380	6139	(1568)	(5942)
Feb	(1890)	829	4423	5676	(3207)	(6164)
Mar	(3858)	26	4829	5020	(3228)	(4365)
Apr	(3414)	(300)	6423	3512	(4111)	(2954)
May	(3214)	823	6928	2585	(4834)	
Jun	(2717)	2057	5825	2638	(5106)	
Jul	(2709)	2039	5733	1193	(5175)	
Aug	(3992)	3061	5143	308	(4509)	
Sep	(3215)	4254	6281	701	(4320)	
Oct	(577)	5338	6282	1403	(3185)	
Nov	251	5933	6494	568	(3896)	
Dec	493	5636	4949	707	(5190)	

Table 6.5 Input Prices for Cow/Calf Herd Expansions/Contractions under Different Scenarios

	Base Case Scenario: April 2005	Scenario 2: Year 2000	Scenario 3: 2002 - May 2003	Scenario 4: June 2003 - April 2004
Calf Price ($/cwt.)	118.60	147.97	128.89	105.19
Cull Cow Price ($/cwt.)	30.50	59.14	56.22	21.04
Bred Heifer Price ($/head)	625.83	1088.16	1042.60	803.62
Feeder Cow Price ($/cwt.)	39.00	63.37	59.53	35.34
Hay Price ($/cwt.)	88.09	75.74	125.56	89.66

Notes: April 2005 prices were obtained from CanFax Daily Market Report; other prices were the average prices over the period specified by scenarios.

Table 6.6 NPV Estimates for Beef Cow Herd Expansion/Contraction under the Base Case Scenario (April 2005)

Expansion/Contraction Decisions	S_1	S_2	NPV
	($)	($)	($)
Expansion			$(S_1 - S_2)$
Expansion with 10 cows	3,534	6,258	-2,724
Expansion with 20 cows	6,406	12,516	-6,110
Contraction			$(S_2 - S_1)$
Contraction with 10 cows	5,406	5,018	-388
Contraction with 20 cows	9,862	10,037	175

Notes: The parameters are defined as following: S_1 = expected economic values of cows in herd expansion; forgone economic values of cows in herd contraction, S_2 = cost of bred heifers in herd expansion; revenue of feeder cows in herd contraction.

Table 6.7 Real Option Values Associated with Decisions to Change Herd Size under the Base Case Scenario (April 2005)

Description	Scenarios for the expansion and contraction			
Time to maturity (years)	Base Case Scenario			
	Option to wait in expansion ($)		Option to wait in contraction ($)	
	10 animals	20 animals	10 animals	20 animals
1 year	34.79	6.73	581.54	1,380.52
2 years	118.41	50.24	859.96	1,851.73
3 years	190.94	106.51	1,059.27	2,190.37
4 years	258.54	166.82	1,210.43	2,445.89
5 years	310.18	218.39	1,334.06	2,655.69
6 years	356.56	265.99	1,436.28	2,829.51
7 years	395.39	308.58	1,521.79	2,974.13
8 years	424.97	342.56	1,595.63	3,099.33
9 years	453.75	376.17	1,660.47	3,209.71
10 years	474.79	402.04	1,718.45	3,309.13

Notes: The extra pasture land rents/cost savings in pasture land rent were not included in the herd expansion/contraction and the option calculation above. Number of time steps used was 60 in the spread option model for all the time to maturity.

Table 6.8 NPV Estimates for Beef Cow Herd Expansion/Contraction under Scenario 2: Best Case (year 2000)

Expansion/Contraction Decisions	S_1	S_2	NPV
	($)	($)	($)
Expansion			$(S_1 - S_2)$
Expansion with 10 cows	11,700	10,882	818
Expansion with 20 cows	22,489	21,763	725
Contraction			$(S_2 - S_1)$
Contraction with 10 cows	11,944	8,051.16	-3,893
Contraction with 20 cows	21,976	16,102.3	-5,873.7

Notes: The parameters are defined as following: S_1 = expected economic values of cows in herd expansion; forgone economic values of cows in herd contraction, S_2 = cost of bred heifers in herd expansion; revenue of feeder cows in herd contraction

Table 6.9 Real Option Values Associated with Decisions to Change Herd Size under Scenario 2: Best Case (year 2000)

Description	Scenarios for the expansion and contraction			
Time to maturity	Scenario 2			
(years)	Option to wait in expansion ($)		Option to wait in contraction ($)	
	10 animals	20 animals	10 animals	20 animals
1 year	1,783.93	2,424.02	265.23	576.16
2 years	2,180.77	3,005.86	640.44	1,283.91
3 years	2,467.59	3,437.74	956.04	1,851.59
4 years	2,671.07	3,732.17	1,215.53	2,313.21
5 years	2,817.02	3,952.50	1,435.36	2,691.14
6 years	2,939.69	4,130.72	1,623.20	3,033.59
7 years	3,036.93	4,280.07	1,783.93	3,321.22
8 years	3,099.46	4,366.17	1,924.66	3,569.51
9 years	3,177.30	4,489.22	2,048.63	3,787.32
10 years	3,216.86	4,547.59	2,159.82	3,981.25

Notes: The extra pasture land rents/cost savings in pasture land rent were not included in the herd expansion/contraction and the option calculation above. Number of time steps used was 60 in the spread option model for all the time to maturity.

Table 6.10 NPV Estimates for Beef Cow Herd Expansion/Contraction under Scenario 3: Pre-BSE (2002 - May 2003)

Expansion/Contraction Decisions	S_1	S_2	NPV
	($)	($)	($)
Expansion			$(S_1 - S_2)$
Expansion with 10 cows	3,990	10,426	-6,436
Expansion with 20 cows	7,303	20,858	-13,555
Contraction			$(S_2 - S_1)$
Contraction with 10 cows	7,224	7,563.29	339.3
Contraction with 20 cows	13,426	15,126.6	1,700.6

Notes: The parameters are defined as following: S_1 = expected economic values of cows in herd expansion; forgone economic values of cows in herd contraction, S_2 = cost of bred heifers in herd expansion; revenue of feeder cows in herd contraction.

Table 6.11 Real Option Values Associated with Decisions to Change Herd Size under Scenario 3: Pre-BSE (2002 - May 2003)

Description	Scenarios for the expansion and contraction			
Time to maturity (years)	Scenario 3			
	Option to wait in expansion ($)		Option to wait in contraction ($)	
	10 animals	20 animals	10 animals	20 animals
1 year	2.37	0.08	1,249.50	2,793.63
2 years	27.50	4.79	1,635.29	3,416.94
3 years	68.30	20.76	1,912.18	3,875.92
4 years	115.63	45.66	2,120.36	4,221.09
5 years	159.43	74.98	2,290.56	4,505.14
6 years	200.34	104.73	2,430.89	4,739.56
7 years	237.21	135.13	2,547.32	4,934.48
8 years	268.81	162.78	2,647.85	5,255.60
9 years	299.34	190.24	2,476.51	5,451.08
10 years	323.54	213.66	2,549.76	5,392.38

Notes: The extra pasture land rents/cost savings in pasture land rent were not included in the herd expansion/contraction and the option calculation above. Number of time steps used was 60 in the spread option model for all the time to maturity.

Table 6.12 NPV Estimates for Beef Cow Herd Expansion/Contraction under Scenario 4: Post-BSE (June 2003 – April 2004)

Expansion/Contraction Decisions	S_1	S_2	NPV
	($)	($)	($)
Expansion			$(S_1 - S_2)$
Expansion with 10 cows	568	8,036.2	-7,468.2
Expansion with 20 cows	571	16,072.4	-15,501.4
Contraction			$(S_2 - S_1)$
Contraction with 10 cows	2,992	4,491	1,499
Contraction with 20 cows	5,408	8,982	3,574

Notes: The parameters are defined as following: S_1 = expected economic values of cows in herd expansion; forgone economic values of cows in herd contraction, S_2 = cost of bred heifers in herd expansion; revenue of feeder cows in herd contraction

Table 6.13 Real Option Values Associated with Decisions to Change Herd Size under Scenario 4: Post-BSE (June 2003 – April 2004)

Description	Scenarios for the expansion and contraction			
Time to maturity (years)	Scenario 4			
	Option to wait in expansion ($)		Option to wait in contraction ($)	
	10 animals	20 animals	10 animals	20 animals
1 year	0.00	0.00	1,555.46	3,574.00
2 years	0.00	0.00	1,647.77	3,621.26
3 years	0.00	0.00	1,744.14	3,727.70
4 years	0.02	0.00	1,819.24	3,824.65
5 years	0.09	0.00	1,883.34	3,907.49
6 years	0.25	0.00	1,936.61	3,984.52
7 years	0.53	0.00	1,980.07	4,045.93
8 years	0.95	0.00	2,018.52	4,100.54
9 years	1.46	0.00	2,053.51	4,151.49
10 years	2.07	0.01	2,085.95	4,199.79

Notes: The extra pasture land rents/cost savings in pasture land rent were not included in the herd expansion/contraction and the option calculation above. Number of time steps used was 60 for all the time to maturity.

Table 6.14 Summary of Findings from the Real Option Analysis in the Cow/Calf Operation

Scenarios	Decision Under NPV	Decision Under Real Option	Implications for Investment Policy[a]	Actual Changes of Herd Size
Base Case Scenario (April 2005)	Contract herd size by 20 cows	Wait for one year before herd contraction	Unless a full recovery of the cattle industry is made by 2007 (e.g. calf price bounce back to $154 per cwt.), herd expansion will not be feasible; selling bred cows for herd contraction may be economically feasible in the next few years	Due to the focus on younger cattle of large processing operations, the ranks of older cattle in the herd have grown.
Scenario 2 – Best Case (2000)	Expand herd size by 10 to 20 cows	Wait for 1 year before herd expansion	Herd expansions are economically feasible given two consecutive years with favorable market conditions; herd contractions are not suggested in 2 years, provided one of them has high cattle prices	The entire population of cows on Alberta farms increased in 2000.
Scenario 3 – Pre-BSE (2002 - May 2003)	Contract herd size by 10 to 20 cows	Wait for 1 year before herd contraction	Expanding herd size will not be in producers' best interests in 2004 unless high calf price is met; herd contractions may be taken in 2003	The entire population of cows on Alberta farms declined slightly in 2002.
Scenario 4 – Post-BSE (June 2003 - April 2004)	Contract herd size by 10 to 20 cows immediately	Contract the herd size by 20 cows immediately	Cows can be resold as bred cows in 2006 to contract herd size if calf price rises; if not, earlier herd contractions in 2005 may be considered	The entire population of cows on Alberta farms has been a decline in 2003. Due to the limited processing capacity in Canada, the collective herd size in Alberta has grown since 2004.

Notes: Implications for investment policy are drawn from the spread option model in the cow/calf sector. [a] The investment policy refers to the guidelines for future investment decision making in the underlying cow/calf operation.

Table 6.15 Real Option Values Associated with Cattle Placement Decision under Fed and Feeder Cattle Price Combinations

Feeder Cattle ($/cwt.) \ Fed Cattle ($/cwt.)	86	87	88	89	90	91	92	93	94	95	96	97
102	$7.4	$15	$30	$53	$94	$158	$257	$403	$609	$892	$1,268	$1,750
103	$4.4	$9.4	$19	$36	$65	$113	$189	$302	$465	$677	$1,006	$1,414
104	$2.7	$6.0	$12	$24	$45	$80	$137	$224	$353	$536	$791	$1,130
105	$1.7	$3.8	$8.0	$16	$31	$56	$98	$164	$265	$410	$615	$897
106	$1.0	$2.3	$5.1	$11	$21	$39	$69	$119	$196	$309	$475	$703
107	$0.6	$1.4	$3.2	$7.0	$14	$27	$49	$85	$144	$231	$361	$545
108	$0.4	$0.9	$2.1	$4.4	$9.2	$18	$34	$60	$104	$169	$272	$418
109	$0.2	$0.5	$1.2	$2.8	$5.9	$12	$23	$42	$74	$123	$202	$318
110	$0.1	$0.3	$0.8	$1.7	$3.8	$7.9	$15	$29	$52	$89	$150	$240
111	$0.1	$0.2	$0.4	$1.1	$2.4	$5.1	$10	$20	$37	$63	$108	$178
112	$0.0	$0.1	$0.3	$0.7	$1.5	$3.3	$6.9	$13	$25	$45	$78	$130
113	$0.0	$0.1	$0.2	$0.4	$0.9	$2.1	$4.5	$9.0	$17.4	$31	$56	$95
114	$0.0	$0.0	$0.1	$0.2	$0.6	$1.3	$2.9	$5.9	$11.7	$21.6	$39	$68
115	$0.0	$0.0	$0.1	$0.1	$0.3	$0.8	$1.8	$3.8	$7.8	$15.6	$27	$49
116	$0.0	$0.0	$0.0	$0.1	$0.2	$0.5	$1.1	$2.5	$5.2	$10.5	$18	$34
117	$0.0	$0.0	$0.0	$0.1	$0.1	$0.3	$0.7	$1.6	$3.4	$6.7	$13	$24
118	$0.0	$0.0	$0.0	$0.0	$0.1	$0.2	$0.4	$1.0	$2.1	$4.5	$8.5	$16
119	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.3	$0.6	$1.4	$2.9	$5.6	$11
120	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.2	$0.4	$0.9	$1.8	$3.8	$7.0
121	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.2	$0.5	$1.2	$2.5	$5.0
122	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.3	$0.8	$1.6	$3.3

(Table 6.15 continued on the next page.)

Notes: All the option value lower than 10 were rounded to one decimal place. All the other model parameters were kept the same as reported in Table 5.3 in calculating the real option values.

(Table 6.15 continued.)

Real Option Values Associated with Cattle Placement Decision under Fed and Feeder Cattle Price Combinations

Feeder Cattle ($/cwt.) \ Fed Cattle ($/cwt.)	98	99	100	101	102
102	$2,350	$3,080	$3,944	$4,945	$6,080
103	$1,931	$2,569	$3,338	$4,243	$5,279
104	$1,572	$2,125	$2,801	$3,609	$4,548
105	$1,267	$1,740	$2,330	$3,044	$3,888
106	$1,011	$1,412	$1,919	$2,547	$3,296
107	$800	$1,135	$1,569	$2,112	$2,771
108	$624	$903	$1,270	$1,735	$2,310
109	$483	$711	$1,017	$1,412	$1,909
110	$370	$554	$806	$1,139	$1,565
111	$280	$428	$634	$911	$1,271
112	$210	$328	$493	$722	$1,023
113	$157	$248	$380	$565	$816
114	$115	$185	$289	$439	$665
115	$84	$137	$218	$338	$504
116	$59	$101	$164	$257	$389
117	$42	$73	$121	$193	$298
118	$29	$52	$89	$145	$228
119	$20	$37	$64	$108	$173
120	$14	$26	$46	$78	$128
121	$9.0	$18	$32	$56	$94
122	$6.0	$12	$22	$43	$69

Table 6.16 Net Profits of Finishing a Pen Associated with Fed and Feeder Cattle Price Combinations in 000s dollars

Feeder Cattle ($/cwt.) \ Fed Cattle ($/cwt.)	86	87	88	89	90	91	92	93	94	95	96	97
102	-23.93	-22.15	-20.37	-18.59	-16.81	-15.02	-13.24	-11.46	-9.68	-7.90	-6.12	-4.34
103	-25.21	-23.42	-21.64	-19.86	-18.08	-16.30	-14.52	-12.74	-10.96	-9.17	-7.39	-5.61
104	-26.48	-24.70	-22.92	-21.14	-19.36	-17.57	-15.79	-14.01	-12.23	-10.45	-8.67	-6.89
105	-27.76	-25.97	-24.19	-22.41	-20.63	-18.85	-17.07	-15.29	-13.51	-11.72	-9.94	-8.16
106	-29.03	-27.25	-25.47	-23.69	-21.91	-20.12	-18.34	-16.56	-14.78	-13.00	-11.22	-9.44
107	-31.58	-29.80	-28.02	-26.24	-24.46	-22.67	-20.89	-19.11	-17.33	-15.55	-13.77	-11.99
108	-31.58	-29.80	-28.02	-26.24	-24.46	-22.67	-20.89	-19.11	-17.33	-15.55	-13.77	-11.99
109	-32.86	-31.07	-29.29	-27.51	-25.73	-23.95	-22.17	-20.39	-18.61	-16.82	-15.04	-13.26
110	-34.13	-32.35	-30.57	-28.79	-27.01	-25.22	-23.44	-21.66	-19.88	-18.10	-16.32	-14.54
111	-35.41	-33.62	-31.84	-30.06	-28.28	-26.50	-24.72	-22.94	-21.16	-19.37	-17.59	-15.81
112	-36.68	-34.90	-33.12	-31.34	-29.56	-27.77	-25.99	-24.21	-22.43	-20.65	-18.87	-17.09
113	-37.96	-36.17	-34.39	-32.61	-30.83	-29.05	-27.27	-25.49	-23.71	-21.92	-20.14	-18.36
114	-39.23	-37.45	-35.67	-33.89	-32.11	-30.32	-28.54	-26.76	-24.98	-23.20	-21.42	-19.64
115	-40.51	-38.72	-36.94	-35.16	-33.38	-31.60	-29.82	-28.04	-26.26	-24.47	-22.69	-20.91
116	-41.78	-40.00	-38.22	-36.44	-34.66	-32.87	-31.09	-29.31	-27.53	-25.75	-23.97	-22.19
117	-43.06	-41.27	-39.49	-37.71	-35.93	-34.15	-32.37	-30.59	-28.81	-27.02	-25.24	-23.46
118	-44.33	-42.55	-40.77	-38.99	-37.21	-35.42	-33.64	-31.86	-30.08	-28.30	-26.52	-24.74
119	-45.61	-43.82	-42.04	-40.26	-38.48	-36.70	-34.92	-33.14	-31.36	-29.57	-27.79	-26.01
120	-46.88	-45.10	-43.32	-41.54	-39.76	-37.97	-36.19	-34.41	-32.63	-30.85	-29.07	-27.29
121	-48.16	-46.37	-44.59	-42.81	-41.03	-39.25	-37.47	-35.69	-33.91	-32.12	-30.34	-28.56
122	-49.43	-47.65	-45.87	-44.09	-42.31	-40.52	-38.74	-36.96	-35.18	-33.40	-31.62	-29.84

(Table 6.16 continued on the next page.)

Notes: Production costs, output and input weights were kept the same as reported in Table 5.3 in calculating the net profits. In the short term, the net profit results approximate the NPVs.

(Table 6.16 continued.)

Net Profits of Finishing a Pen Associated with Fed and Feeder Cattle Price Combinations in 000s dollars

Feeder Cattle ($/cwt.) \ Fed Cattle ($/cwt.)	98	99	100	101	102
102	-2.56	-0.77	1.01	2.79	4.57
103	-3.83	-2.05	-0.27	1.51	3.29
104	-5.11	-3.32	-1.54	0.24	2.02
105	-6.38	-4.60	-2.82	-1.04	0.74
106	-7.66	-5.87	-4.09	-2.31	-0.53
107	-10.21	-8.42	-6.64	-4.86	-3.08
108	-10.21	-8.42	-6.64	-4.86	-3.08
109	-11.48	-9.70	-7.92	-6.14	-4.36
110	-12.76	-10.97	-9.19	-7.41	-5.63
111	-14.03	-12.25	-10.47	-8.69	-6.91
112	-15.31	-13.52	-11.74	-9.96	-8.18
113	-16.58	-14.80	-13.02	-11.24	-9.46
114	-17.86	-16.07	-14.29	-12.51	-10.73
115	-19.13	-17.35	-15.57	-13.79	-12.01
116	-20.41	-18.62	-16.84	-15.06	-13.28
117	-21.68	-19.90	-18.12	-16.34	-14.56
118	-22.96	-21.17	-19.39	-17.61	-15.83
119	-24.23	-22.45	-20.67	-18.89	-17.11
120	-25.51	-23.72	-21.94	-20.16	-18.38
121	-26.78	-25.00	-23.22	-21.44	-19.66
122	-28.06	-26.27	-24.49	-22.71	-20.93

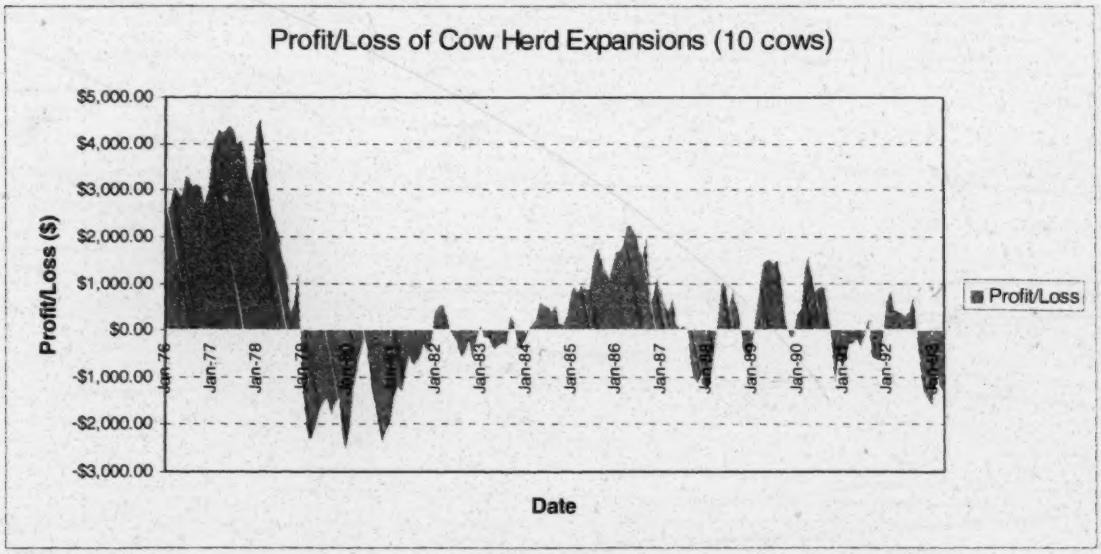
Table 6.17 Percentage Change of Option Value in the Feedlot Operation to Reduction in Production Costs

Percentage Reduction in Production Costs	Option Value	% Change Option Value
	($ /Pen)	
10%	1.66	86.75%
20%	10.3	83.88%
30%	52	80.19%
40%	209.17	75.14%
50%	674.28	68.98%

Notes: Option Values are calculated using the model parameters in Table 5.3. The option value without any reduction in production costs was $0.2/Pen.

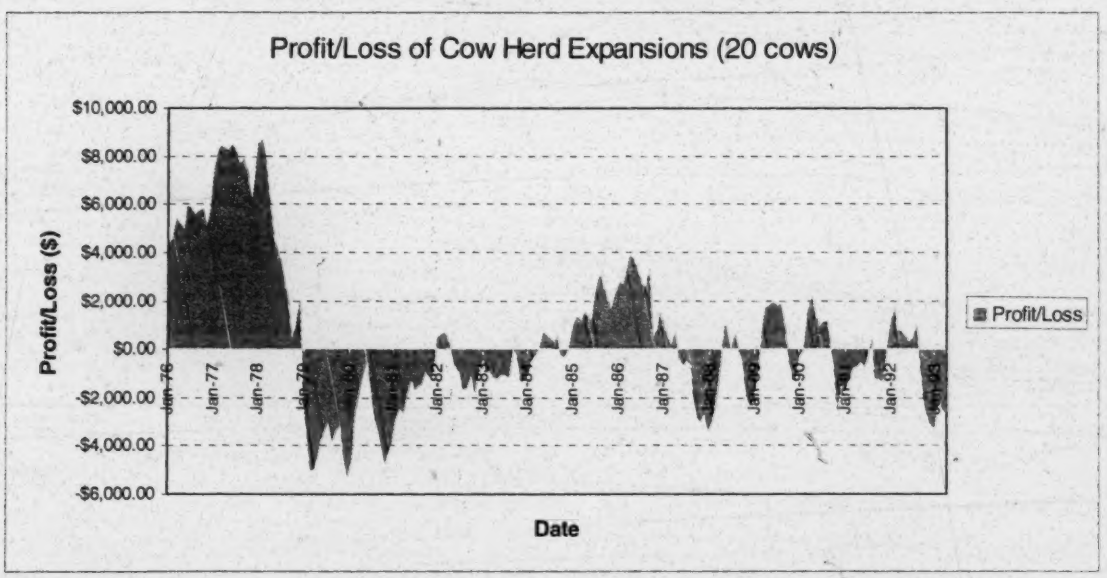
6.5 Figures for Chapter 6

Figure 6.1 Profit/Loss Results for Expansion of 10 Cows in the Cow/Calf Operation



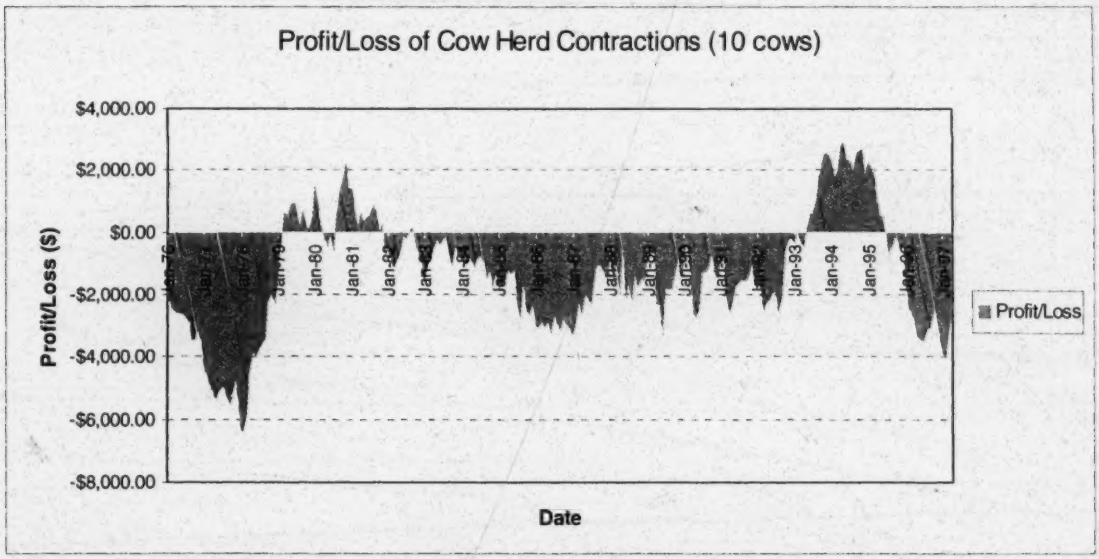
Notes: Profits/losses were simulated using the expect values of outcomes from biological distributions. Areas above/below the x-axis denote the profits/losses associated with expansion of 10 cows.

Figure 6.2 Profit/Loss Results for Expansion of 20 Cows in the Cow/Calf Operation



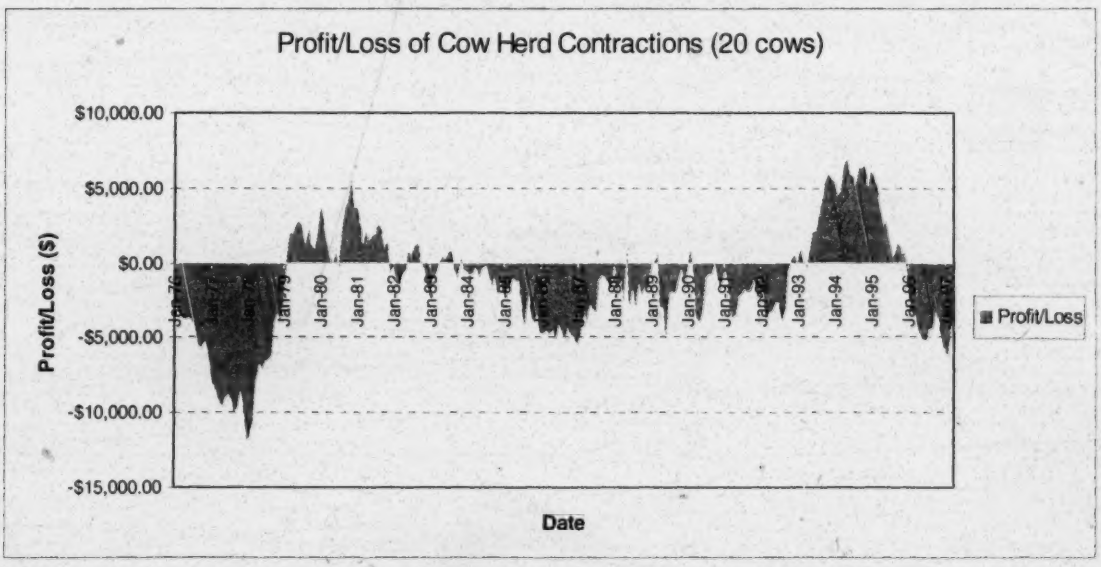
Notes: Profits/losses were simulated using the expect values of outcomes from biological distributions. Areas above/below the x-axis denote the profits/losses associated with expansion of 20 cows.

Figure 6.3 Profit/Loss Results for Contraction of 20 Cows in the Cow/Calf Operation



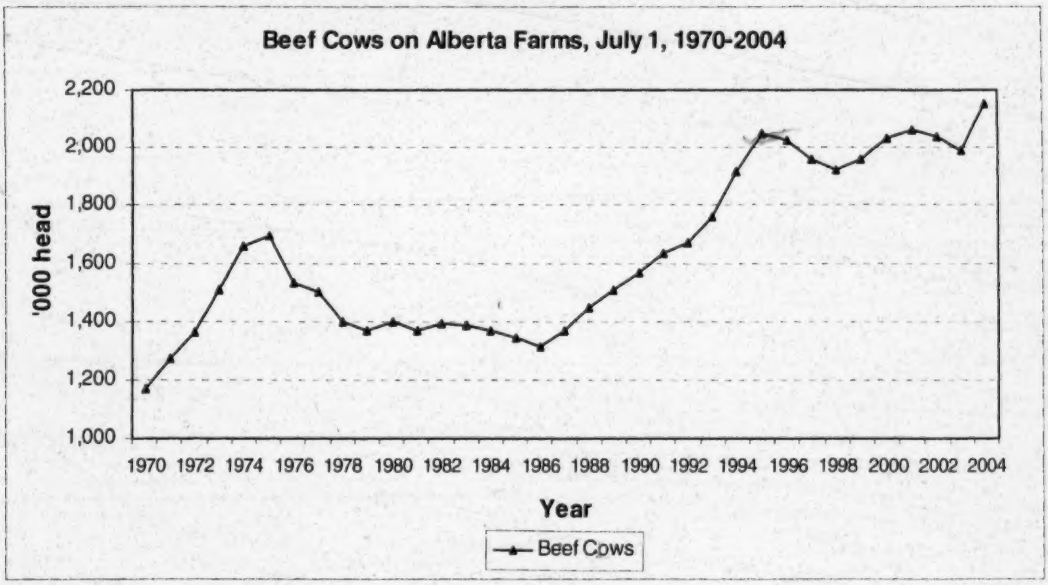
Notes: Profits/losses were simulated using the expect values of biological distributions. Areas above/below the x-axis denote the profits/losses associated with contraction of 10 cows.

Figure 6.4 Profit/Loss Results for Contraction of 10 Cows in the Cow/Calf Operation



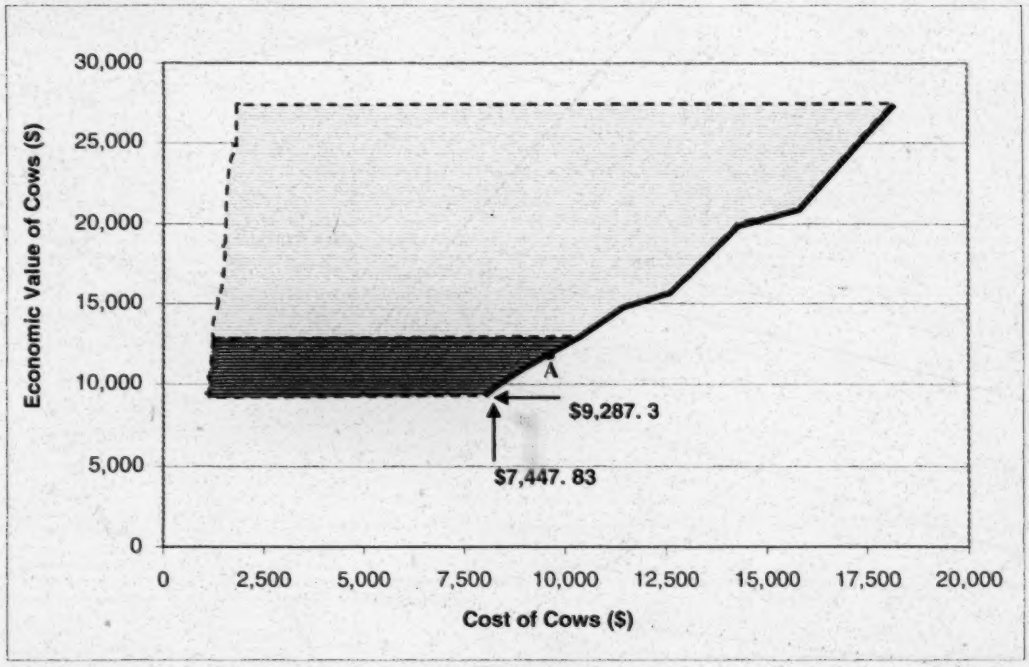
Notes: Profits/losses were simulated using the expect values of biological distributions. Areas above/below the x-axis denote the profits/losses associated with contraction of 20 cows.

Figure 6.5 Beef Cows on Alberta Farms, 1970-2004



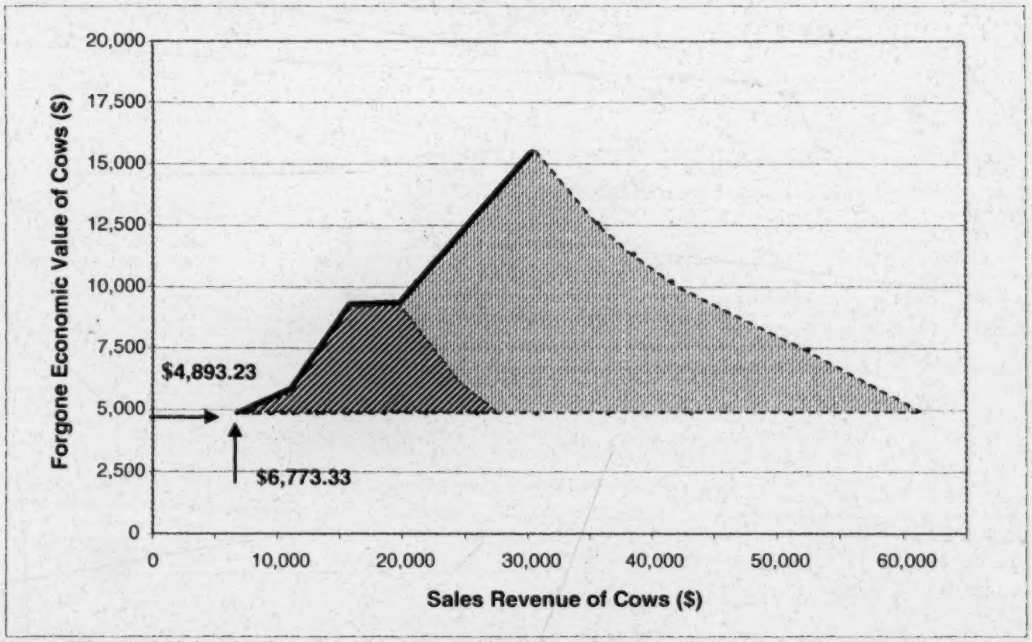
Source: AAFRD, "Alberta Agriculture Statistics Yearbook", 2004.

Figure 6.6 Expansion Thresholds of 10 Cows in the Cow/Calf Operation in 2007 under the Base Case Scenario (April 2005)



Notes: The dark/light shading denotes the combinations of asset values for herd expansion with higher/lower cumulative probabilities to occur in year 2007.

Figure 6.7 Contraction Thresholds of 10 Cows in the Cow/Calf Operation in 2007 under the Base Case Scenario (April 2005)



Notes: The dark/light shading denotes the combinations of asset values for herd contraction with higher/lower cumulative probabilities to occur in year 2007.

Figure 6.8 Expansion Thresholds of 10 Cows in the Cow/Calf Operation in 2008 under the Base Case Scenario (April 2005)

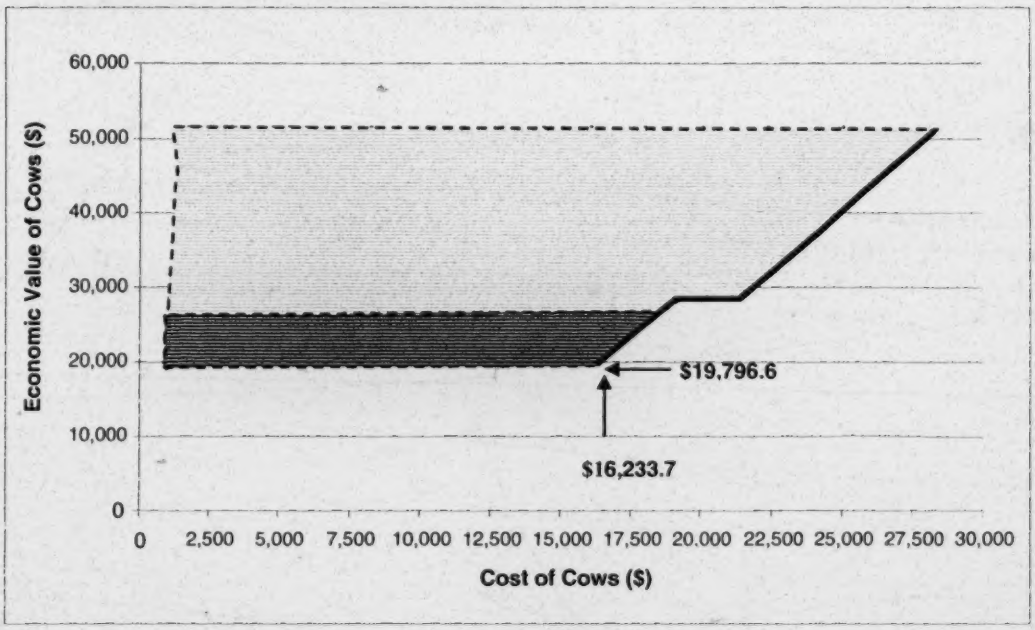


Figure 6.9 Contraction Thresholds of 10 Cows in the Cow/Calf Operation in 2008 under the Base Case Scenario (April 2005)

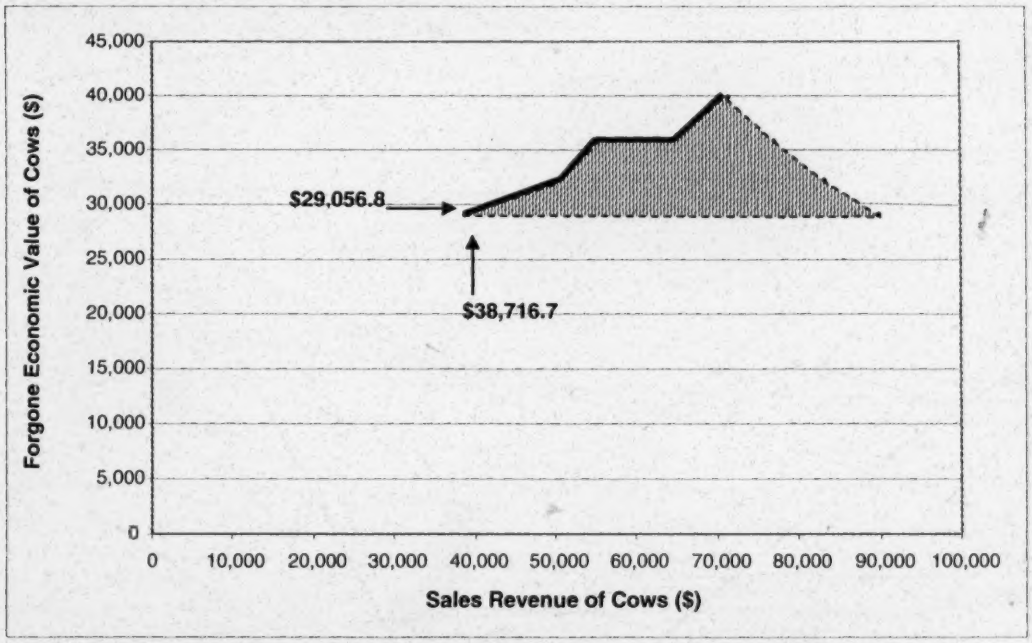


Figure 6.10 Expansion Thresholds of 10 Cows in the Cow/Calf Operation in 2002 under Scenario 2: Best Case (year 2000)

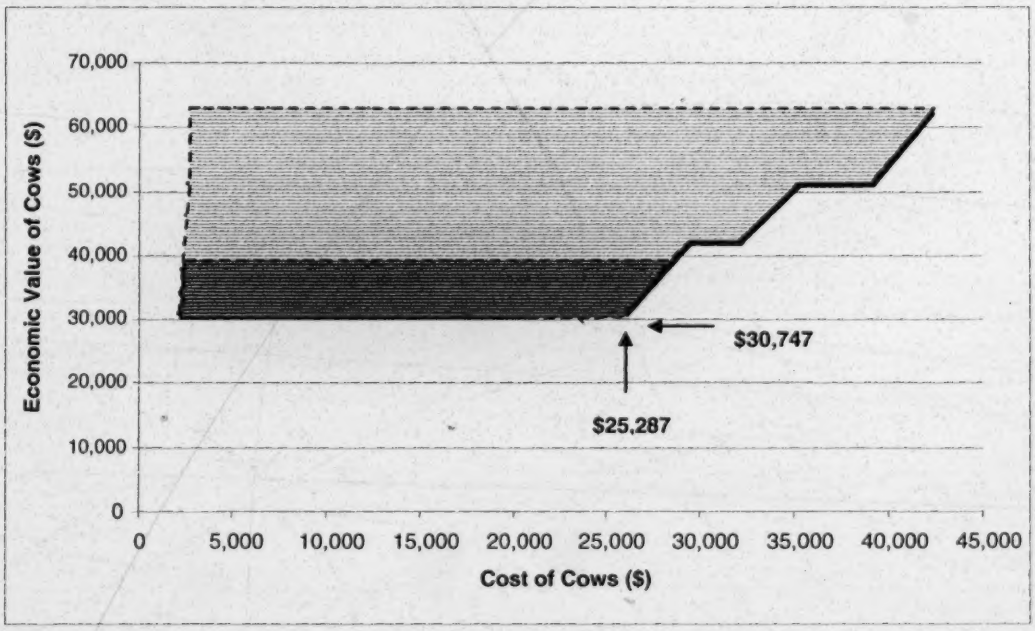


Figure 6.11 Contraction Thresholds of 10 Cows in the Cow/Calf Operation in 2002 under Scenario 2: Best Case (year 2000)

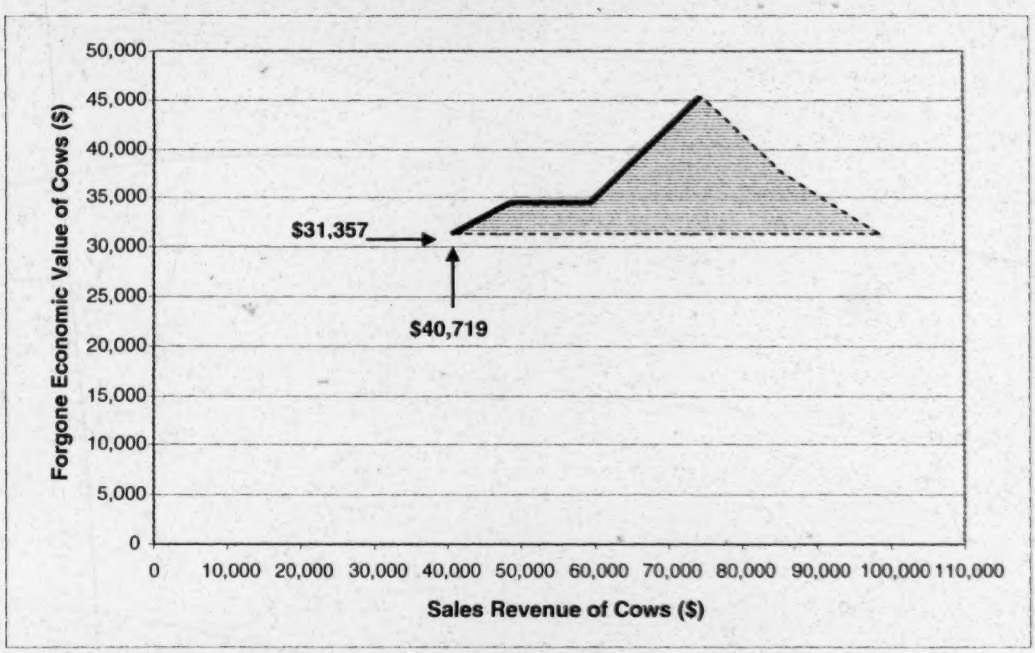


Figure 6.12 Expansion Thresholds of 10 Cows in the Cow/Calf Operation in 2005 under Scenario 3: Pre-BSE (2002-May 2003)

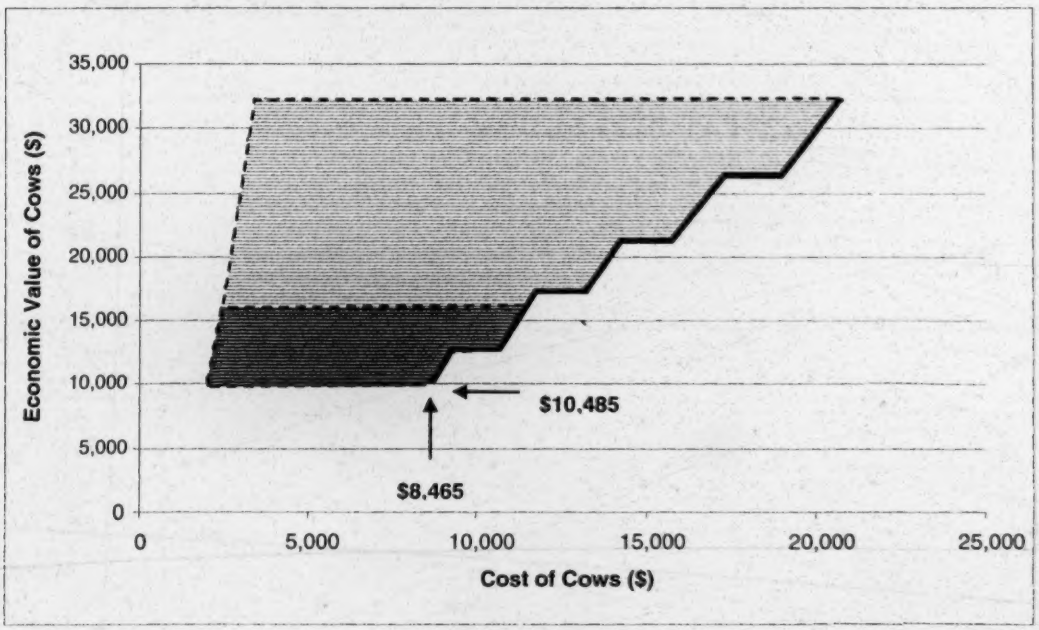


Figure 6.13 Contraction Thresholds of 10 Cows in the Cow/Calf Operation in 2005 under Scenario 3: Pre-BSE (2002-May 2003)

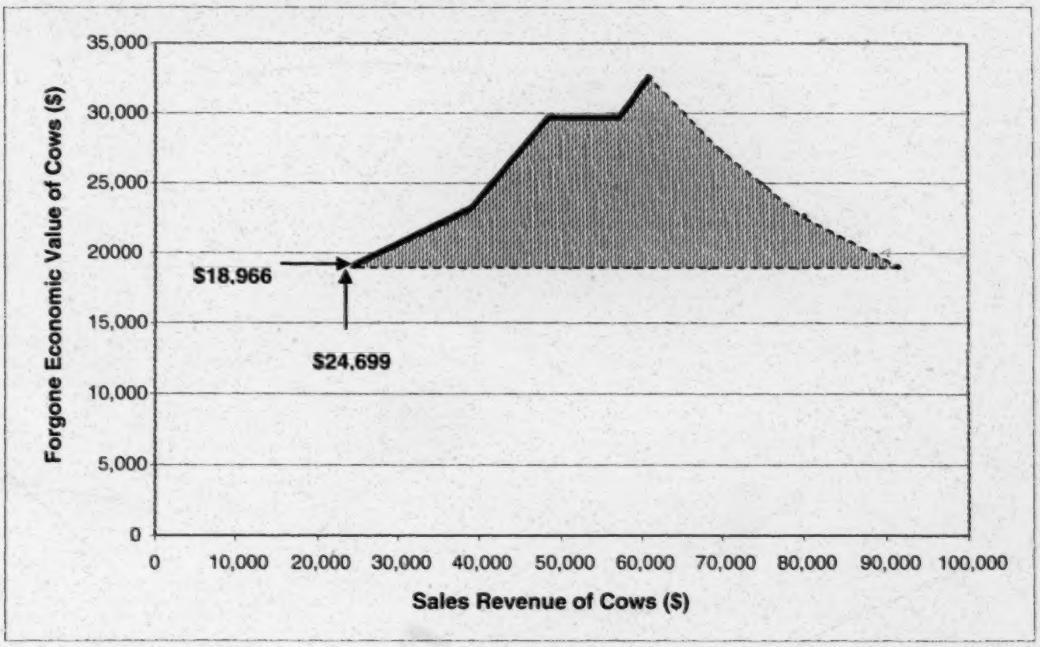
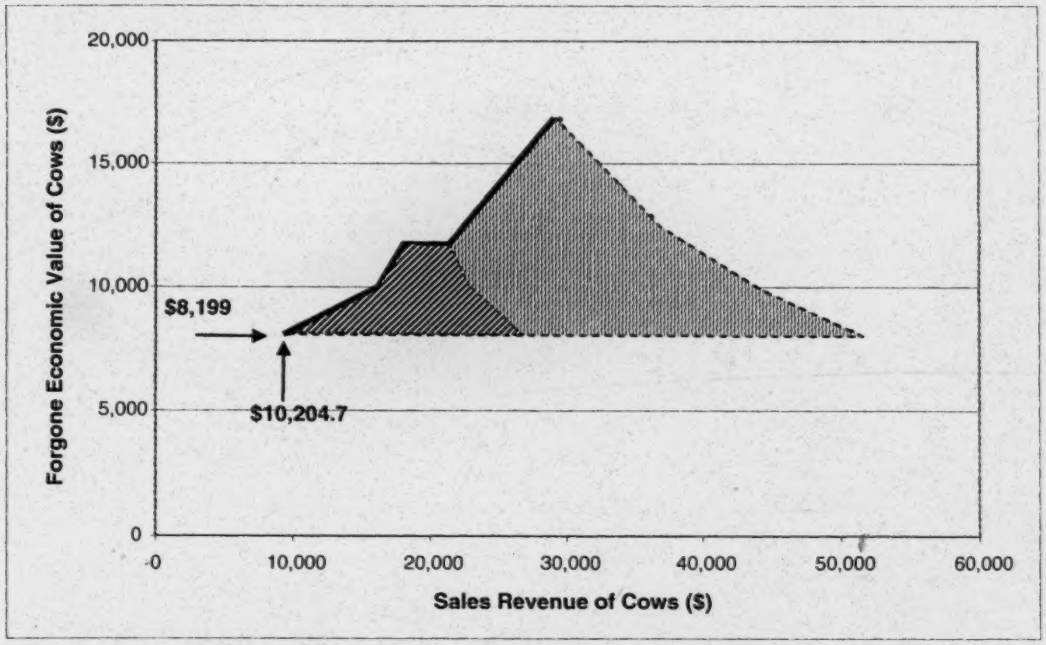


Figure 6.14 Contraction Thresholds of 10 Cows in the Cow/Calf Operation in 2006 under Scenario 4: Post-BSE (June 2003-April 2004)



Notes: The dark/light shading denotes the combinations of asset values for herd contraction with higher/lower cumulative probabilities to occur in year 2006.

Figure 6.15 The Effect of Changes in Volatility on Option to Wait Values in the Decision to Expand Herd Size in the Cow/Calf Operation

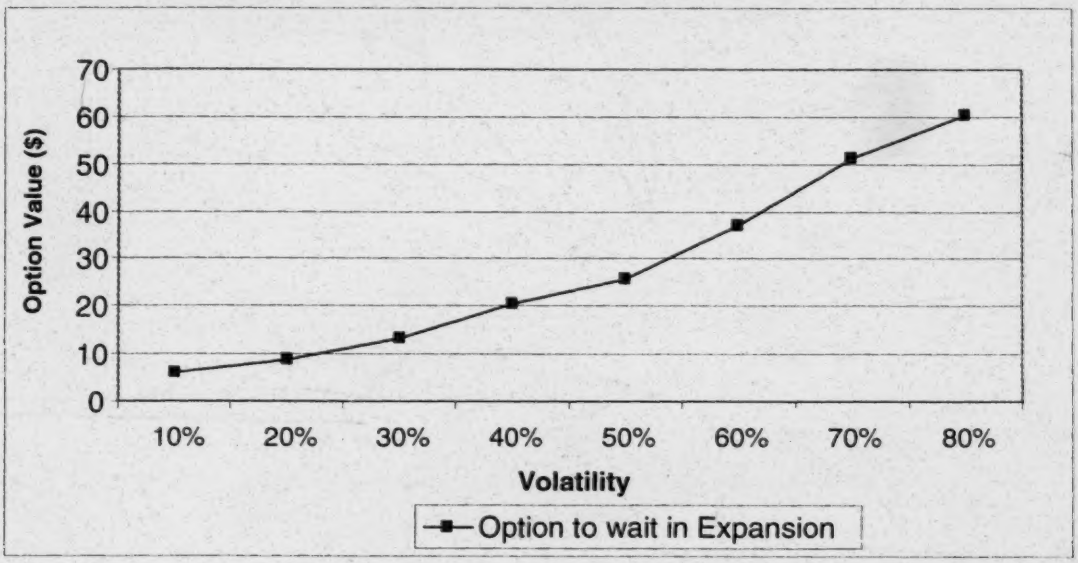


Figure 6.16 The Effect of Changes in Volatility on Option to Wait Values in the Decision to Contract Herd Size in the Cow/Calf Operation

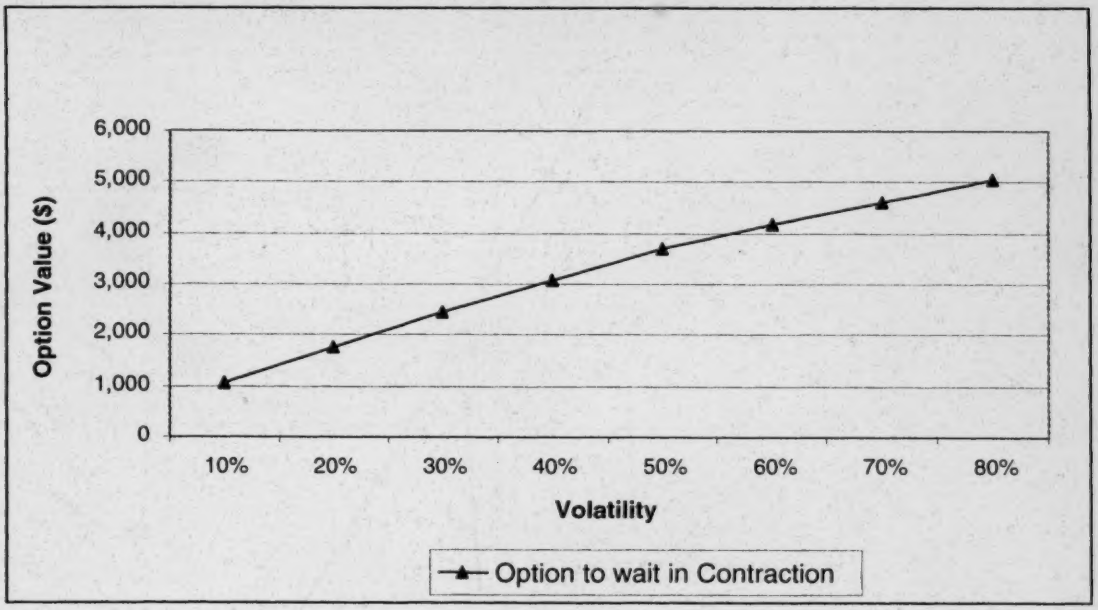
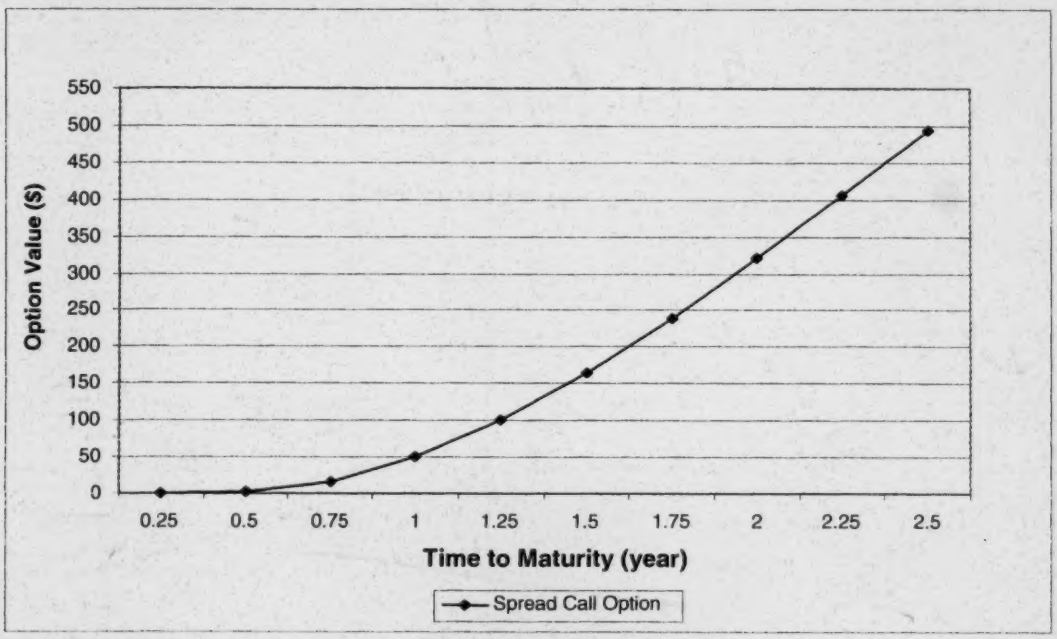
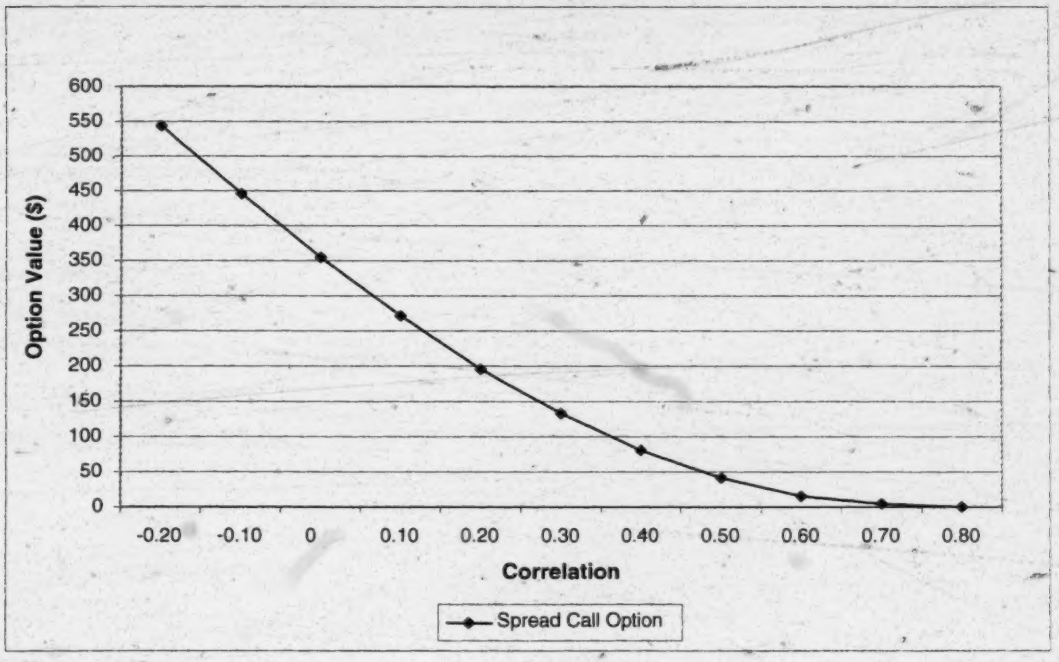


Figure 6.17 Sensitivity of Option Value to Changes in the Time to Maturity in the Feedlot Operation



Notes: Other model parameters were the same as reported in Table 5.3.

Figure 6.18 Sensitivity of Spread Option Value to Changes in the Correlation between the Two Asset Returns in the Feedlot Operation



Chapter 7: Conclusions and Limitations

Consolidation into larger specialized beef cattle operations has exposed beef cattle producers to the specific sources of risk associated with the operations. In order to make sound capital investment decision in the cattle operation under uncertainty, the real options approach was applied to the Alberta cattle industry in this study. The objective is to evaluate the principles, issues, usages and applicability of the real options approach as an innovative capital budgeting method in the investment decision making in cow/calf, backgrounding, and feedlot sectors. The existence of real option values may enable better understanding of how future risk and uncertainty affect cattle producers' investment decision. This chapter presents conclusions based on the results from analyses in the previous chapters. Limitations of the study along with suggestions for future research in this area are discussed.

7.1 Traditional Capital Budgeting Method Conclusions

As a foundation for the potential application of the real options approach as an innovative capital budgeting tool for aiding cattle producers in investment decision-making, traditional capital budgeting methods used to evaluate agricultural investment decisions at the farm level were reviewed. An investment is economically profitable if it is expected to return a profit on the initial investment. Traditionally, it is evaluated in one of four ways: the projected cash flow (ability to make loan payment), the payback period, net present value, and internal rate of return.

From the existing literature and survey results, it is concluded that the net present value which summarizes the expected net cash flow produced by the investment into a single number that is adjusted for risk, inflation and the time value of money is the most widely recommended technique in capital budgeting. However, at the farm level, there has been a lack of NPV applications compared with other capital budgeting methods.

Although NPV is highly recommended by the academics, recent developments in investment analysis have shown that the NPV is limited in coping with uncertainty and does not value the ability of the investor to react to changing market conditions (Dixit & Pindyck, 1994; Collins & Hanf, 1998; Copeland &

Antikarov, 2001). In fact, the total value of the investment project is its economic value based on its cash-flow forecasts plus its strategic value. And its strategic value is the sum of its managerial flexibility expressed as real options. Hence, real option values may add to the value of the investment project. Discounted cash flow analysis (e.g. net present value) of a decision without taking real option values into account can lead management to neglect valuable opportunities.

The real options approach is an emerging model based on financial option principles for investment decision in real assets that attempts to capture the value of managerial flexibility, especially when flexibility is reduced by capital-intensive and specialized investments whose effects would last for several years (Dixit & Pindyck 1994; Trigeorgis 1995). The recent streams of the real options literature have attempted to value investments in a wider range of industries. This study adds to the existing literature by considering the application of the real options approach in the cattle industry.

7.2 Simulation Model and Real Option Analysis Conclusions

By considering the importance to the cattle producers and the deficiency in previous research, the following investment decisions were identified for the real option analyses: the decision to expand/contract breeding herd size in the cow/calf operation, the keep-or-sell feeder cattle decision in the summer backgrounding operation, and the decision when to place an additional pen of feeder cattle on feed in the feedlot operation. Based on the attributes of the production timeline, payoff patterns and sources of risk associated with these investment decisions, real options inherent in the investment decisions were identified as: spread call/put option, put option with stochastic strike prices, and spread call option respectively.

Based upon the literature review of different option valuation models, the put option in the summer backgrounding operation can be modeled by the Monte Carlo simulation algorithm which is capable of pricing American options with multiple risky assets. However, setting up the MCS algorithm is beyond the scope of this thesis. The numerical solution to the put option in the summer backgrounding operation is not studied.

The real options in the cow/calf and feedlot operations were evaluated using the spread option algorithm developed by Rubinstein (1994). The estimation of the spread option parameters associated with the cow/calf operation was accomplished by using computer software to simulate historical returns from the economic value of cows over the years from 1976 to 2004. The empirical model was programmed in an Excel spreadsheet. The critical output from the model was the historical economic value of bred heifers/breeding cows bought/sold in herd expansions/contractions. The conclusions based on the results provided by the simulation model and real option analyses are discussed as follows.

7.2.1 Historical Simulation Model Conclusions

Historical simulation-based procedures generated estimates of the economic value of beef cows in herd expansions and contractions. The model parameters were calculated from the geometric annual returns of the economic values of cows. As validation of the simulation model, herd expansion or contraction decisions based on the historical profit/loss results of the simulation were consistent with the actual changes of beef cow population on Alberta farms. Based on the estimated volatility parameters, it was concluded that as the size of the expansion or contraction increased from one cow to 20 cows, the return of the economic values of cows in the expansion/contraction became less volatile because multiple units in herd expansion/contraction help diversify the production risks.

However, it was also concluded the increase of the number of cows in herd expansion/contraction reduced the variations in the return of the economic value of cows at the expense of incurring lower average economic values of cows. This result would probably result in higher feasibilities of smaller herd expansions (contain less bred heifers) under favorable market conditions and larger herd contractions (contain more old cows) under unfavorable market conditions.

Overall, the historical simulation model of returns of herd expansion/contraction was quite innovative and effective in measuring the volatility of returns from cows in herd expansion/contraction and in estimating the other parameters for the real option model in the cow/calf operation. In addition, the

historical simulation model developed in this study can solve more than just the specialized case of cow/calf operations. Given the right set of historical prices, the model could also measure the volatility of return from changing operating scales of other livestock and non-agricultural products.

7.2.2 Real Option Analysis Conclusions

The purpose of this study has been to determine if the real option theory is applicable in the investment decision analysis with regard to changing herd size in the cow/calf operation, keeping or selling feeder cattle in the backgrounding operation, and placing feeder cattle on feed in the feedlot operation. And if so, estimate the option values associated with the underlying investment decisions and access the impact of real option values on the decision making in the three sectors of the cattle industry.

In this study, we have developed a decision framework considering the option to wait value in changing cow herd size in the cow/calf operation. The valuable option to wait is likely to arise in producers' decisions to vary herd size because of the irreversible costs involved, uncertain returns and opportunity to invest in the future. According to the real option results, there existed significant real option values inherent in the decisions to change herd size. However, since the calculations of the underlying economic value of cows rely on simplified assumptions regarding future cattle prices, a different set of economic values of cows generated by cattle price forecasting models may result in different option values.

Nevertheless, the real option values had an important impact on not only the investment decisions today but also the investment policy to follow during a specified period of time. Under the NPV framework, the breeding herd should have been expanded in 2000 and contracted immediately in 2002-2003 and April 2005, but the real option values altered these decisions and suggested the producers to wait for at least 1 year for clearer market evidences. This result had demonstrated that recognizing the option to wait inherent in an investment may have a significant impact on the investment project value and hence investment decision-making. In Scenario 4: Post-BSE (June 2003-May 2004), a herd contraction decision which was

consistent with the observed decline in cow population on Alberta farms was indicated under the real options framework. However, the real option results may not be interpreted to explain the increase in herd size actually observed after the BSE crisis as a result of limited supply of domestic processing capacity in Canada. When compared to some of the historical changes that occurred in the entire cow population on Alberta farms, decisions made under the real options framework did not follow the reality more closely than the decisions made under the NPV framework.

Implications for individual investment policy associated with the decision to change herd size within a specified period of time can be drawn from the expansion/contraction thresholds by analyzing the early exercised nodes in the three-dimensional spread option space. The thresholds of the decision to expand or contract in a certain period of time can be implemented into the investment policy. For example, under the prevailing prices in April 2005, unless a full recovery of the Alberta cattle industry is made by 2007 (e.g. calf price bounces back to $154 per cwt.), herd expansion may not be feasible. On the other hand, selling bred cows as a means of herd contraction may be economically feasible in the next few years. One particularly interesting result was that the option to wait value in herd contractions in the Base Case Scenario (April 2005) may provide one explanation as to the non-decreasing herd size after the BSE crisis. Due to the lognormality assumptions of the economic value of cows and cost of bred heifers in conjunction with the geometric Brownian motion, thresholds of the economic value of cows and cost of bred heifers/sales revenue of cows extracted from the early exercised nodes in the spread option model, especially when the time to maturity goes beyond 2 years, appear unrealistic. Nevertheless, the innovative insights regarding future investment policies have not been provided by other traditional capital budgeting models before.

The spread call option value arising from the decision when to place a pen of feeder cattle in the feedlot provided less interesting results. The majority of the option to wait values were not large enough to be considered with the net profits of the feedlot operation. This occurred because of the negative price spread between fed and feeder cattle prices, high production cost, short time to maturity and the high correlation between feeder cattle and fed cattle prices. The assumption of fixed

production cost and failure to account for the correlation between the returns of the feed grain price and the feeder cattle price may also cause incorrect option results.

The overall conclusion of this study is that the real options approach has the potential to be a capital budgeting tool used by farm managers for aiding long-term investment decisions in the cattle industry, especially in the cow/calf sector because of the degree of risk and the long investment horizon. The real option approach is capable of capturing the value of managerial flexibility under uncertainty when flexibility is reduced by capital-intensive and specialized investments. Implications for future investment policy can be drawn from the thresholds extracted from the early exercised nodes in the real option models. The thresholds for the investment/disinvestment decision in the future can be used as benchmarks for investment policy design and implementation. However, estimation of the economic value of cows is based on simplified assumptions with regard to future cattle prices. Cattle prices predicted by forecasting models may change the economic value estimations and the real option results. Caution should be suggested in interpreting the threshold values and embodying model assumptions such as the lognormality distribution of the underlying assets. Performance implications of the real option models in the cattle operations require empirical evidence and future research.

7.3 Limitations and Further Research

7.3.1 Geometric Brownian Motions Assumption

Perhaps the greatest limitation of this study is the need to assume the economic value of cows, cost of bred heifers/cows, feeder and fed cattle prices follow geometric Brownian motions (GBM). It implies that regardless of the pattern (e.g. mean reversion) of multiple, correlated sources of cash flows (cattle prices) that a productive asset is expected to have, the changes in its combined present value will follow a random walk (Copeland and Antikarov, 2001). Although the simple random distributions of the logarithm of economic value of cows have shown a general pattern of normal distribution, the assumption of GBM in the spread option models embodies some unrealistic implications for the behavior of cattle prices. Mostly, it assumes that the expected value and variance of cattle price rise without bound,

which means GBM has no structural power to redirect price expectations back toward long-run equilibriums. As is noted by Schwartz (1997), basic microeconomic reasoning would suggest that a relatively high commodity price attracts more higher-cost producers to enter the market. With more producers in the market, the supply of that commodity would increase which in turn puts downward pressure on prices, and vice versa. Henee, this behavior of real commodity prices including beef cattle prices is more likely to result in a Mean Reverting price path than one that follows GBM which is an unlikely price path over the long term.

In dealing with multiple risk factors expressed as stochastic processes, more advanced option pricing technique such as the least square Monte Carlo simulation (LSM) can be employed. The benefit of the LSM approach is in its ability to handle any type of stochastic process in addition to the standard GBM, which is assumed in this study. The LSM uses least square regression techniques to estimate the conditional expected payoffs from the continuation.

7.3.2 Production Assumptions

Several generalized production assumptions are made due to insufficient data. These assumptions are held constant throughout the model, and include factors such as the size of the cow/calf operation, the size of the pen in the feedlot operation, ADG, production timeline of feedlot operations. Thus, further research could avoid the production assumptions used in the models and estimate using actual data instead. It is also assumed in the study that volatilities of historical cow herd returns provide potential indicators of the risk associated with cow/calf operations. Once other risk indicators such as volatility of actual historical returns of individual operations are available, it is worthwhile to check the results with the alternative volatility parameters.

The production costs included in the models are actual historical production data, statistics based on historical data, and proxies derived from previous studies or other similar studies due to the limited data. Most of the production data were used as fixed numbers throughout the cow/calf operation and the feedlot operation. The results of this study could change if newer data from better data sources or models

that measure stochastic variations associated with production costs were obtained to improve estimates used in this research.

Finally, this study was oriented toward a cow/calf operation which purchases replacement animals for herd expansions and a 150 head per pen feedlot operation. The methodology could also accommodate other alternative enterprises such as cow/calf operation producing its own replacements and feedlot operations with different pen sizes.

7.3.3 Catastrophe Production Risks

The discovery of bovine spongiform encephalopathy (BSE) in May 2003 has been a significant cost to Canadian cattle industry. The announcement of bovine spongiform encephalopathy (BSE) - commonly called mad cow disease in one cow in northern Alberta on May 20, 2003 led to a decision by more than 40 countries to immediately impose import restrictions on live ruminant animals (cattle, sheep, goats, bison, elk, deer), meat products and animal by-products from Canada. According to Statistics Canada (2004), the direct economic cost to the Canadian cattle industry by early 2004 was estimated at nearly $3.3 billion. An additional loss in equity to the cow-calf sector was estimated at $3.0 billion, for a total economic impact from BSE of $6.3 billion.

In light of the great impact on income and regulatory uncertainty caused by catastrophe like BSE to the cattle industry, it may be wise to incorporate catastrophic production risks in the simulation model, such as those resulting in large variations in production and market prices. The introduction of catastrophic production risks could have large influences on the operating cash flows and the degree of uncertainty measured by volatility. The results of the real option models could change if catastrophe production risks were included to improve the estimate of the uncertainty in the cattle operations.

7.3.4 Suggestions for Further Research

Further studies may look at other stochastic processes of the economic value of cows and cattle prices such as the mean reverting process or use time series models for predicting cattle prices to enable more accurate estimates of the underlying asset

values in the real option models. The real option analysis of the decision to change herd size in the cow/calf operation in this study was based on two risky real assets in the option payoffs while the put option in the backgrounding operation involves multiple sources of risk. The valuation and optimal exercise of American options remains a challenging problem in derivative finance, particularly when more than one factor affects the value of the option. There are extensive research activities in process trying to solve the complexity of optimal exercise of American options. As mentioned earlier, more flexible option pricing model, such as the least square Monte Carlo simulation with the ability to handle any type of stochastic process and multiple risk factors can be employed in continued research to evaluate the identified investment decision in the cow/calf operation. The flexibility expressed as put options to allow producer sell feeder cattle at lighter weights according to market conditions during the backgrounding process can be explored further using the MCS.

Despite the growing stream of real option applications to evaluate investment in various industries, currently there still exists a large gap between theory and empirical evidence (Dixit & Pindyck, 1994; Schwartz & Trigeorgis, 2001). Research is required to investigate the empirical performance implications of firms that use real option models to evaluate investment opportunities. Direct evidence on whether these valuations using real options actually benefit firms in some ways needs to be provided. In the cattle industry, with a long record of observed market prices and well documented changes in cattle population, a test might be to examine the exercise policy of the cattle producers to measure whether changes in operating scales did actually occur at the optimal point predicted by the option-based model.

Using the real option techniques employed in this study, investment with regard to changing operating scale under uncertainty in other livestock operations including swine, dairy, and sheep can be studied. The historical simulation model provided a methodology of incorporating both market risks and production risks into a comprehensive volatility measure. The methodology could also accommodate non-agricultural products.

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Appendix A – Capital Asset Pricing Model and Capital Market Line

The most important issue identified in NPV calculation is the treatment of risk (Weldon and Moss, 1994). In an NPV analysis, the future cash flows are discounted at a so-called "discount rate". In order to use the NPV approach introduced in Section 2.1.1, there should be appropriate procedures for farmers to estimate their unique discount rates reflecting the project risk they have undertaken. Modern finance theory provides several models to estimate the risk adjusted discount rate for the NPV model. The Capital Market Line (CML) and the Capital Asset Pricing Model (CAPM) are two approaches commonly used to adjust the cost of capital for capital budgeting (Brigham and Gapenski, 1997).

CAPM Approach

In order to determine whether the risk adjusted discount rate be estimated by the CAPM or the CML, the risk of holding risky assets is divided into systematic risk and specific risk (Sharpe, 1964). Systematic risk is the risk of holding the market portfolio. Each individual asset is more or less affected by the overall market performance. Specific risk is the risk which is unique to an individual asset. Investors are compensated by the marketplace for taking systematic risk, but not for taking specific risk because specific risk is diversifiable (Wilmott, 2001).

CAPM was originally a model describing the relationship between risk and expected return that was used in the pricing of risky securities. The sensitivities of a portfolio or a project to broad market movements are measured by so-called Beta coefficients (Fama and French, 2004). The stock market (represented by an index such as the S&P 500) is assigned a beta of 1.0 as a benchmark. The expected return of a security or a diversified portfolio equals the rate on a risk-free security plus a risk premium while risk is defined in terms of volatility, as measured by the denominator of the investment's beta coefficient. The formula for beta is as following (Brigham and Gapenski, 1997):

$$\beta = \frac{\mathrm{cov}(\overline{R}_P, \overline{R}_M)}{\sigma_m^2} \qquad \text{(A.1)}$$

where $cov(\overline{R}_P, \overline{R}_M)$ is the covariance between the expected portfolio (or project) return and the market return, and σ_m^2 is the variance of the market's return (its volatility squared).

The CAPM formula is given as (Ross et al., 2002):

$$\overline{R} = R_F + \beta \times (\overline{R}_M - R_F) \qquad (A.2)$$

where $\overline{R}$ = Expected returns on a security; R_F = Risk free rate; β = Beta of the security; $\overline{R}_M$ = Expected market returns (like the S&P 500). Investors require higher levels of expected returns to compensate them for bearing higher expected risk. Therefore, $\overline{R}$ can also be considered as the risk adjusted discount rate a well diversified investor would use to evaluate investment projects.

However, in determining the risk adjusted discount rate for the NPV model of an investment project, the validity of the CAPM may still be an empirical question (Emery and Finerty, 1997; Fama and French, 2004). Although there has been limited work done at the farm level to measure beta coefficients for agricultural operations, Tauer (2002) did a regression analysis in the context of the CAPM to estimate the cost of equity of 62 New York dairy farms. The estimated farm betas were exceptionally low and could not reflect the true risk and return of these farms. Tauer concluded the CAPM was not the appropriate procedure to estimate the risk adjusted discount rate for these individual dairy farms. One possible explanation of this empirical failure is that the farmers' investment portfolios may not be as diversified as stock investors (Perold, 2004).

CML Approach

In agriculture, and particularly for most farms, due to capital constraint and lifestyle considerations (i.e. the reluctance to disinvest from agriculture), there may be a limited ability to reduce the specific risk through diversification into other assets. Thus, farm investment portfolios are often non-diversified and are associated with high level of specific risk. Since the CAPM was designed to measure only systematic risk using beta after taking diversification benefits into account (Brigham and

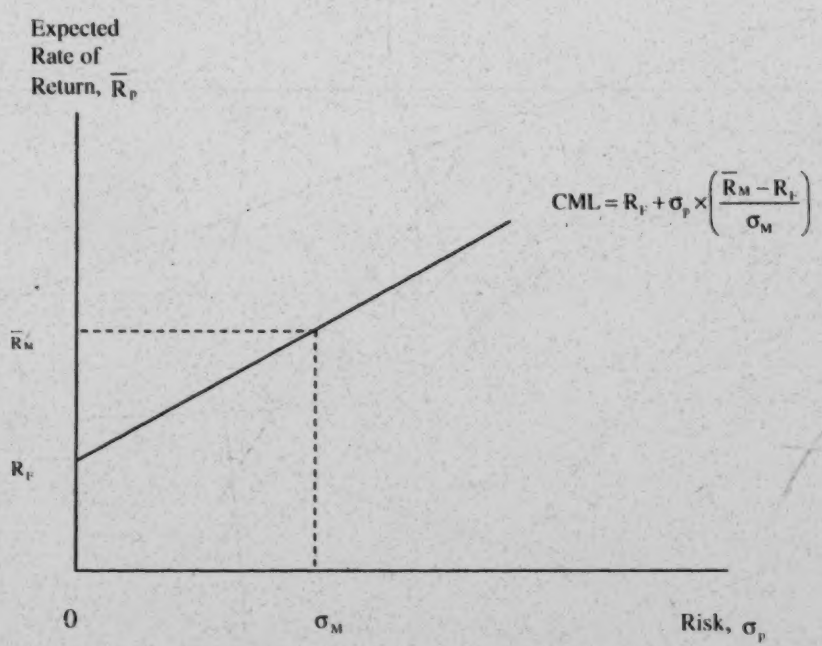
Gapenski, 1997), the CAPM may not be the correct approach when applied to agricultural investments.

The Capital Market Line (CML) provides an alternative for calculating expected returns that incorporates the total risk of a project as reflected by its standard deviation. The equation for the CML is given as (Brigham and Gapenski, 1997):

$$\overline{R}_p = R_F + \sigma_p \times \left(\frac{\overline{R}_M - R_F}{\sigma_M} \right) \qquad (A.3)$$

where $\overline{R}_p$ = Expected return on the project; R_F = Risk free rate; σ_p = the standard deviation of the project returns; $\overline{R}_M$ = Expected market return (like the S&P 500); σ_M = the standard deviation of the market returns. Figure A.1 illustrates the CML.

Figure A.1 Capital Market Line



Source: Adapted from Brigham and Gapenski, 1997, pg. 208.

The slope of the CML in Figure A.1 represents the risk-return tradeoff that an efficient portfolio of assets provides. Riskier projects should require higher expected returns and therefore higher discount rates should be used for evaluating such projects (Ross et al., 2002). In the CML equation, the total risk (both systematic and specific risk[37]) of a project is measured by its standard deviation instead of the beta coefficient as in the CAPM.

As a result, when the well diversified portfolio assumption is relaxed, it is possible that the discount rate provided by the CML can be more appropriate for determining the level of expected returns that non-diversifiable agricultural investments would require. This level of expected return is then used as the discount rate for NPV analysis. Therefore, all specific risk associated with the investment project is included in the calculation of the discount rate. The risk adjusted discount rates used in this study are calculated from the CML because beef cattle operations usually constitute a large portion of a rancher/cattle feeder's portfolio. These risk adjusted discount rates may be overstated if cattle producers' portfolio is diversified to some extent (e.g. when cattle production is combined with grain growing enterprises).

[37] In financial theory, an efficient portfolio is assumed to be one that is well diversified. Therefore, all the specific risk of an efficient portfolio is usually eliminated by diversification.